DISSERTATION

NUTRIENT COMPOSITION AND SENSORY ATTRIBUTES OF BEEF FROM GRAIN-FINISHED STEERS AND HEIFERS

Submitted by

Rebecca Jean Acheson

Department of Animal Sciences

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Doctoral Committee:

Advisor: Dale R. Woerner

J. Daryl Tatum
Terry E. Engle
Keith E. Belk
Marisa L. Bunning

ABSTRACT

NUTRIENT DATABASE IMPROVEMENT PROJECT: NUTRIENT COMPOSITION OF RETAIL CUTS FROM THE BEEF LOIN AND ROUND

Over the past decade, nutrient composition of beef became an increasingly important topic both domestically and internationally for the beef industry and its consumers. Beef is an important source of protein, monounsaturated fatty acids, conjugated linoleic acid, vitamins and minerals. Due to evolutionary changes in production practices and fabrication techniques the current nutrient data in the USDA National Nutrient Database for Standard Reference has become outdated. The objectives of these studies were to determine the nutrient composition of ten beef loin and round retail cuts to update the USDA National Nutrient Database for Standard Reference (SR). Seventy-two carcasses representing a national consist of yield grade, quality grade, and genetic type were identified from six regions across the U.S. Beef short loins, strip loins, tenderloins, inside rounds, and eye of rounds (IMPS # 173, 175, 190A, 169A, and 171C) were collected from the selected carcasses and shipped to three university meat laboratories for storage, retail fabrication, and raw/cooked analysis of nutrients. Sample homogenates from each animal were analyzed for proximate composition, as well as fatty acid, cholesterol, vitamin, and mineral content. Data from this study were intended to update SR information regarding the nutrient status of beef and to determine the influence Quality Grade, Yield Grade, and sex classification have on proximate composition. This study identified four Upper Choice, seven Low Choice, and eight Select cuts that qualify for the lean nutrient claim based on cooked separable lean values. Results from the cooked beef loin samples indicate that beef is a good source of iron, vitamin B2, and phosphorus, and an excellent source of selenium, zinc, and

vitamins B3, B6, and B12. The nutrient data provided will be utilized to help update nutritional labels of beef products and to help design future dietary interventions that include beef as a protein source.

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CHAPTER I

INTRODUCTION

Since the early 1980's per capita beef consumption in the United States has steadily decline. Before the early 1980's, epidemiological research studies were published linking saturated fat, total fat, and cholesterol intake to chronic diseases such as coronary heart disease (Keys, 1970; Keys et al., 1971; Keys et al., 1972). As a result of these studies, starting with the 1977 Dietary Goals for the United States, government-issued dietary guidance has highlighted the need for Americans to decrease total fat, saturated fat, and cholesterol intake, while increasing the amount of polyunsaturated and monounsaturated fatty acids in the diet (USDA-USDHH, 2005; USDA-USDHH, 2010). In order to decrease consumption of total and saturated fat, many Americans chose to eat less beef. A consumer survey of 2000 American adults revealed that a majority (53%) of the respondents believed that red meat was the "least healthy protein" choice as compared to poultry, fish, or pork (Mintel Oxygen, 2008). Interestingly, during this same time period, obesity rates continued to increase even as Americans reduced the amount of beef consumed in their daily diet (CDC, 2008).

Over the past 30 years, the beef industry has made tremendous strides in offering a lean, nutrient dense protein product. Due to beef production and fabrication practices, average saturated fat content has declined 17% since 1963 (Watt and Merrill, 1963). In addition, cohort studies have revealed that lean beef is an important source of B-vitamins, iron, zinc, and selenium (Zanovec et al., 2010; Nicklas et al., 2012). However, many Americans still believe that beef is an unhealthy protein source due to its total fat and saturated fat content (American Dietetic Association, 2008; International Food Informational Council Foundation, 2009). Recent studies have highlighted the role of lean beef in a healthy diet (Roussell et al., 2010; Zanovec et

al., 2010; Nicklas et al., 2012). Roussell et al. (2010) reported that consuming lean beef as a part of the daily diet can lower blood cholesterol levels to the same extent as the Dietary Approaches to Stop Hypertension (DASH) diet. In addition, many researchers have suggested that lean beef can have a positive impact on Type-2 diabetes and sarcopenia (Leslie et al., 2002; Campbell, 2007; Layman et al., 2008; Campbell and Tang, 2010; Phillips, 2012). As prevalence of chronic diseases continue to increase and as consumers continue to live to increasingly advanced ages, it is important that the beef industry provides consumers and health-care officials with updated nutrient information to help consumers make healthy choices.

In addition to providing a nutrient dense product, it is important that the beef industry continue to produce a high quality product. Overall eating experience is most likely the reason most Americans consume beef. Most researchers consider tenderness one of the most important factors influencing beef sensory experience. Tenderness has consistently been cited as one of the top five beef quality challenges in the industry (Smith et al., 1992, 1995a, 2000). As a result, the beef industry has focused on ways to provide a consistently tender product. The current USDA maturity classifications were designed to help separate beef produced by animals of different physiological age. As an animal ages, the concentration of heat-stable collagen crosslinks in muscle increases, resulting in a tougher product. As a result, beef produced by animals of advanced age receives substantial price discounts (USDA, 2013).

In the United States, a majority of fed steers and heifers are under 30 months of age and produce A maturity carcasses that do not receive price discounts. However, the most recent National Beef Quality Audit reported that approximately 7% of carcasses of grain-finished steers and heifers are classified as B maturity or older (Moore et al., 2012) likely due to premature skeletal ossification. As a result of being classified as B-maturity, these carcasses receive price discounts due to perceived reductions in tenderness. Research studies have not consistently supported this price discount since a

consistent relationship between USDA maturity classification and tenderness has not been defined in grain-finished steers and heifers (Miller et al., 1983; Field et al., 1997). Studies suggest that beef produced from grain-finished animals that are of a similar age is similar in overall tenderness, regardless of maturity classification (Miller et al., 1983; Field et al., 1997). As a result, the price discount for more “mature” carcasses may be unjustified. In addition, current USDA Quality Grade standards may be limiting the supply of Choice and Select beef and decreasing the value captured by the beef industry.

In order to continue to meet consumer demand, research related to beef quality will remain a top research priority. However, as more consumers try to make educated food choices, it will become increasingly important for the beef industry to provide the nutrition community and consumers with updated beef nutrient composition information that reflects the current retail supply. The objectives for the first three studies were to determine the nutrient composition of beef retail cuts from the loin and round by utilizing proximate, fatty acid, cholesterol, vitamin, and mineral analysis. The objective of the fourth study was to compare sensory properties of beef from A maturity and B maturity or older carcasses produced by grain-finished steers and heifers classified as less than 30 MOA by dentition.

CHAPTER II

REVIEW OF LITERATURE

Since 1977, the Dietary Guidelines for Americans have encouraged consumers to reduce their consumption of total fat, saturated fat, and cholesterol. Since that time, per capita consumption of beef decreased due to health concerns and price. The most recent Dietary Guidelines for Americans were released in 2010. The two main themes for the 2010 Guidelines were to maintain calorie balance over time to achieve and sustain a healthy weight and to consume nutrient dense foods. The 2010 Guidelines emphasized the importance of limiting the intake of sodium, total fat, saturated fat, *trans* fat, refined grains, sugar, and alcohol. Less than 30% of caloric intake should result from fat consumption. Saturated fats and *trans* fats should make up less than 10% and 1%, respectively, of total caloric intake. In addition, cholesterol intake should remain below 300 mg per day to prevent hypercholesterolemia and obesity. The 2010 Dietary Guidelines for Americans recommended: increasing the amount and variety of vegetables and fruits, consuming at least half of all grains as whole grains, choose a variety of protein foods, including lean meats, poultry, eggs, beans, and nuts, increase the amount and variety of seafood, and increase the intake of fat-free and low-fat dairy products (USDA-USDHH, 2010).

As a result of over 30 years of nutritional guidelines recommending a decrease in total fat, saturated fat, and cholesterol, Americans have begun to make attempts to reduce these foods from their diets. Unfortunately, due to many epidemiological studies, many health influencers and consumers believe that in order to reduce these nutrients they must reduce or eliminate their consumption of red meat, specifically beef. A consumer survey of 2000 American adults showed that 53% believed red meat was the “least healthy protein” choice compared to poultry, fish, or

pork (Mintel Oxygen, 2008). A recent Food and Health Survey revealed that 63% of Americans are trying to consume less animal fat (International Food Information Council Foundation, 2009). Another study by the American Dietetic Association (2008) indicated that 41% of survey respondents decreased their consumption of beef between 2002 and 2008. The Dietary Guidelines for Americans are highly respected by many health influencers, and as a result, have shaped the way many consumers view the role of red meat in a healthy diet.

Lipids

In the human diet, lipids are a broad group of naturally occurring molecules which are essential to many of the body's processes. The functions lipids have in the body include, but are not limited to: storing energy, serving as structural membranes, aiding in cell signaling, function as biological detergents, and carrying fat soluble vitamins. Unlike protein and carbohydrates, all lipids do not share one characteristic structural similarity, which allows lipids to be grouped into classes based on chemical structure. Classes of lipids are non-esterified fatty acids, glycerolipids, glycerophospholipids, sphingolipids, isoprenoids, waxes, steroids, and eicosanoids. Most foods are comprised of a mixture of these compounds. The Dietary Guidelines for Americans (USDA-USDHH, 2010) recommend that adults consume 20 to 35% of their total calories in the form of fat.

Non-esterified Fatty Acids

Non-esterified fatty acids, or free fatty acids, are characterized by a carboxylic acid head group and a hydrocarbon chain tail. The hydrocarbon chain is made up mostly of single carbon-carbon covalent bonds. Free fatty acids can range from two to forty carbons in length, but are typically 12 to 22 carbons in length. Fatty acid synthase adds two carbon acetyl-CoA units to the chain at a time to form free fatty acids. Free fatty acids are further classified by chain length

(short, medium, or long) and degree of saturation or number of double bonds (saturated, monounsaturated, or polyunsaturated). Short-chain fatty acids are less than eight carbons in length; medium chain fatty acids are eight to 14 carbons in length; and long-chain fatty acids are over 14 carbons in length. Fatty acids make up over 90% of a fat molecule; therefore, the fatty acid type can determine properties of fat (Martin and Coolidge, 1978). Aroma, physical state (i.e., liquid vs. solid at room temperature), flavor, and shelf-life stability are all properties that lipid contribute to food products.

Saturated Fatty Acids

Saturated fatty acids (SFA) refer to a hydrocarbon chain in which all of the carbon atoms are saturated with hydrogen and a single covalent bond connects each carbon (Martin and Coolidge, 1978; Stipanuk, 2000). Saturated fats are solid at room temperature and have a higher melting point than unsaturated fatty acids of the same chain length (Martin and Coolidge, 1978). In addition, saturated fatty acids are more stable and oxidize less readily than unsaturated fatty acids.

The Dietary Guidelines for Americans (USDA-USDHH, 2010) recommend that adults consume less than 10% of total calories from saturated fatty acids. In many developed countries, dietary guidelines have aimed at reducing consumption of saturated fatty acids in the diet due to their correlation with coronary heart disease. Early human studies implicated all saturated fats as having a role in increasing total and low-density lipoprotein (LDL) blood cholesterol levels (Chizzolini et al., 1999; Maki et al., 2012). More recent studies indicated that not all saturated fats have the same effect on blood cholesterol (Hu et al., 1999; Kelly et al., 2002; Mensink et al., 2003). These studies revealed lauric, mysteric, and palmitic fatty acids have a negative effect on total cholesterol and low-density lipoprotein (LDL) cholesterol. Other major saturated fatty

acids, such as stearic acid, have a neutral effect on blood cholesterol (Kelly et al., 2002; Mensink et al., 2003). Recent studies reported that SFA intake was not directly associated with an increase in CHD (Pietinen et al., 1997; McNeill et al., 2012).

Unsaturated Fatty Acids

Unsaturated fatty acids contain a hydrocarbon chain that is not "saturated" and contains at least one double bond between carbons (Martin and Coolidge, 1978). Unsaturated fatty acids are differentiated into monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). Monounsaturated fatty acids have one double bond connecting adjacent carbons in the hydrocarbon tail, while polyunsaturated fatty acids have two or more double bonds. Unsaturated fatty acids are the main component in fats that are liquid at room temperature. Due to their chemical structure, unsaturated fatty acids oxidize more readily. Numerous studies have sought to determine the role of unsaturated fatty acids in the human diet. Monounsaturated and polyunsaturated fatty acids have a beneficial role in the diet, helping to reduce total and LDL cholesterol levels. The Dietary Guidelines for Americans (USDA-USDHH, 2010) recommend that adults consume a majority of their fat calories in the form of MUFAs and PUFAs.

Some unsaturated fatty acids, such as oleic acid (18:1), can by synthesized de novo, while other unsaturated fatty acids must be consumed in the diet. Mammals lack the desaturase enzyme needed to add a double bond past the ninth carbon in an 18 carbon chain. As a result, long chain polyunsaturated fatty acids, such as linoleic and alpha-linolenic fatty acids, must be consumed in the diet. Fatty acids that cannot be synthesized de novo are considered "essential" fatty acids. Linoleic and alpha-linolenic acid also are known as omega-6 and omega-3 fatty acids, respectively. This nomenclature refers to the location of the last double bond from the methyl end of the hydrocarbon tail.

Alpha-linolenic acid and linoleic fatty acids serve as the foundation for other long-chain omega-3 and omega-6 fatty acids. Alpha-linolenic acid can be used to form eicosapentaenoic acid (EPA; 20:5) and docosahexaenoic acid (DHA; 22:6). The human body can synthesize small amounts DHA and EPA from alpha-linolenic acid. However, humans do not have the ability to synthesize adequate amounts of DHA and EPA, so they must be consumed as a part of the diet. Arachidonic acid (AA; 20:4) can be formed from linolenic acid through desaturation and elongation reactions. Arachidonic acid, DHA, and EPA are precursors for eicosanoid production which regulates inflammation and immunity in the human body. Prostaglandins, prostacyclins, thromboxanes, and leukotrienes are all synthesized from omega-3 or omega-6 fatty acids. When these eicosanoids are synthesized from omega-6 fatty acids, such as AA, they tend to be pro-inflammatory and immunosuppressive. Eicosanoids are associated with increased blood clotting, increased cell adhesion and decreased blood vessel diameter. Eicosanoids produced from omega-3 fatty acids are non-immunosuppressive, non-adhesive, and anti-inflammatory. Omega-3 fatty acids are known for their role in cognitive development and reducing the risk for coronary heart disease (CHD). Due to the characteristics of eicosanoids, it is beneficial to have the proper balance of omega-6 and omega-3 fatty acids in the human diet. Recommendations for daily intake range from 250 to 500 mg/d (USDA-USDHH, 2010; AHA, 2013).

Trans Fatty Acids

Unsaturated fatty acids with at least one double bond in the *trans* configuration are termed *trans* fatty acids (TFA). *Trans* fatty acids are made either industrially through the partial hydrogenation of vegetable oils to be used in processed foods, or naturally through rumen hydrogenation of fats in cattle. The effects of partially hydrogenated vegetable oils (PHVO) and ruminant derived fatty acids on human health are different. In epidemiological studies, *trans* fats

from PHVO were associated with a higher risk for CHD, while ruminant derived trans fatty acids have not been associated with an increased CHD risk (Huth, 2007). Clinical studies indicated that high levels of *trans* fatty acids from PHVO raised plasma LDL levels similarly to how lauric acid and mysteric acid raise LDL levels in humans (Huth, 2007). Ruminant *trans* fatty acids have a neutral or potentially beneficial effect on LDL cholesterol, HDL cholesterol, and total triglycerides (Terpstra, 2004; Tricon et al., 2004). Higher intake of industrial *trans* fatty acids are associated with increased tumor necrosis factor alpha activity, increased concentrations of C - reactive protein, and increased interleukin 6 concentrations leading to increased inflammation (Huth, 2007). Due to the negative effects of *trans* fatty acids, in 2006, it became mandatory to declare *trans* fat on the nutrition facts label (Scollan et al., 2006).

The different effects on human health are a result of presence of differing fatty acids in PHVO-and ruminant-derived products. *Trans* octadecadienoic acids (18:1 *trans* delta 4-16) are the prominent *trans* fats contributed by PHVO and ruminant derived products. Of the octadecadienoic acids, *trans* vaccenic acid (18:1 delta 11) contributes from 43% to 60% of the total 18:1 *trans* fatty acids derived from ruminant products (Huth, 2007). *Trans* vaccenic acid serves as the precursor to the beneficial conjugated linoleic acids. In industrial PVHO, eleidic acid (*trans* 18:1 delta 9) and *trans* 18:1 delta 10 are the predominant TFA (Huth, 2007).

In 2005, the average American consumed 5.84 g of *trans* fats per day (USDA-USDHH, 2005). Nearly 80% of the *trans* fats consumed in the United States comes from processed foods such as cakes, cookies, pies, potato chips, margarine, etc. (USDA-USDHH, 2005; Huth, 2007). Naturally formed *trans* fats in animal derived products made up the other 20% of *trans* fat consumed in the United States (USDA-USDHH, 2005; Huth, 2007). The Dietary Guidelines for

Americans (USDA-USDHH, 2010) recommend that Americans consume less than 1% of their total calories from *trans* fat.

Conjugated Linoleic Acid

Conjugated linoleic acid is a collective term for a mixture of geometric and positional isomers of linoleic acid (18:2) (Williams et al., 1983; Tanka, 2005). In these isomers, the double bonds in the hydrocarbon chain are not separated by a methylene group, leading to conjugated double bonds. Bacterial isomerases in the rumen lead to the partial hydrogenation of some fatty acids (Williams et al., 1983). Seventy-five to ninety percent of the total CLA in ruminant fat is cis-9, trans-11 (rumenic acid) (Tanka, 2005). The second most prevalent isomer is trans-7, cis-9, which represents 3 to16% of total CLA in ruminant products (Tanka, 2005). Studies on human and mouse models have shown CLA to: prevent cholesterol-induced coronary heart disease; reduce total body fat; enhance immune response; inhibit carcinogenesis; improve diabetes; and improve bone metabolism (Tanka, 2005; Scollan et al., 2006).

Triglycerides

Over 90% of fatty acids exist in ester linkages to a glycerol backbone, not as free fatty acids. Glycerolipids or acylglycerols are formed by combining a three carbon sugar backbone (glycerol) with up to three individual fatty acids. Mono-, di-, and tri-acylglycerides refer to the number of fatty acids chemically linked to the glycerol backbone. Triglycerides are the major form of lipid in the body and 85% of the body's stored energy is in the form of triglycerides. Triglycerides are concentrated metabolic energy with nine calories per gram. The three fatty acids linked to the glycerol backbone in triglycerides can all be the same, or can be different.

Cholesterol

Cholesterol is comprised of a hydrocarbon tail, four hydrocarbon rings, and a hydroxyl group. Cholesterol serves as the parent compound for the biosynthesis of many hormones produced in the body including androgens, estrogens, progestagens, glucocorticoids, and mineral corticoids. Cholesterol is an essential component of cell membranes due to its role in modulating membrane compressibility, permeability, and thickness. In addition, cholesterol is the precursor for bile salts that help digest and absorb fat and fat-soluble vitamins in the small intestine. Cholesterol is only found in products from animal origin, since it is an essential component for cell membranes.

Cholesterol is synthesized in adequate quantities by the body; therefore, it is not an essential nutrient. The Dietary Guidelines for Americans (USDA-USDHH, 2010) recommends consuming 300 mg or less per day of cholesterol. Research reported dietary cholesterol had little to no effect on serum cholesterol levels (Chizzolini et al., 1999).

Phospholipids

Glycerophospholipids or phospholipids are structurally similar to triacylglycerides except that glycerol is esterified to only two fatty acids along with a phosphate group. The five common phosphate head groups that can be esterified to glycerol are phosphatidylethanolamine, phosphatidylcholine, phosphatidylserine, phosphatidylglycerol, and phosphatidylinositol. Phospholipids are a major component of cell membranes and membranes of intracellular organelles. Phosphatidylcholine and phosphatidylethanolamine are the main phosphate head groups found in membrane phospholipids. Phospholipids are essential to the cell membrane due to their amphipathic properties allowing them to form a lipid bilayer with other molecules. The negatively charged head group is hydrophilic while the hydrocarbon chain is hydrophobic.

Bilayers are formed when the hydrophilic head groups are pulled outward by polar charges, thus allowing the hydrophobic tails to aggregate together in the middle. Other important components of the lipid bilayer include cholesterol, protein, acylglycerols, and sphingolipids.

Lipids in Beef

Beef serves as the largest single source of monounsaturated fatty acids in the average American's diet (Nicklas et al., 2012). Leheska et al. (2008) determined that beef contained SFA, MUFA, and PUFA concentrations of 45.1%, 51.6%, and 3.4%, respectively. Stearic, palmitic, and oleic acids comprise approximately 80% of the fatty acids in bovine tissues (Eichhorn et al., 1985).

The lipid fraction of beef is of primary importance due to its role in meat quality. As the amount of intramuscular fat in the *Longissimus dorsi* increases, the USDA Quality Grade increases. A greater amount of marbling reflects higher amounts of total intramuscular lipid, which is mainly composed of triglycerides (Miller et al., 1987a). Due to muscle type and function, cuts from the hind-quarter are typically leaner than muscles from the chuck, rib, and loin. Phospholipid and cholesterol proportions increase as total triglyceride decreases in muscle products (Bodwell and Anderson, 1986). In addition to the impact on human health, the fatty acid profile can affect the flavor profile of foods and shelf-life. Beef contains a very favorable fatty acid profile that can be beneficial in a healthy, balanced diet.

Effects on Lipid Content

Extensive research has determined many that factors contribute to the total lipid quantity and lipid composition of beef, such as finishing system, USDA Quality Grade, sex, breed, cooking method, and external fat trim.

Effect of finishing system

Over the past two decades, consumer interest in the type of finishing system utilized for beef production has varied. Research studies indicated that finishing system can have an impact on total fat content and fatty acid profile of the final meat product (Williams et al., 1983; Leheska et al., 2008; Duckett et al., 2009). Meat products from grain-finished cattle have a higher lipid content and lower moisture content than meat products from their grass-finished counterparts (Williams et al., 1983; Leheksa et al., 2008; Duckett et al., 2009). Leheska et al. (2008) and Duckett et al. (2009) reported 36% and 42.5%, respectively, less total lipid in the *Longissimus dorsi* of grass-finished cattle compared to grain-finished cattle. The lipid content differences in these cattle were a result of greater intramuscular fat (marbling) content in grain-finished cattle versus grass-finished cattle. Leheska et al. (2008) attributed the greater amount of intramuscular fat deposition in grain-finished cattle to a higher energy diet.

Finishing system also impacts overall fatty acid profile of meat products (Williams et al., 1983; Rule et al., 2002; Leheksa et al., 2008; Duckett et al., 2009). Effects of diet are reduced in ruminants as compared to non-ruminants due to the biohydrogenation of the rumen. Leheska et al. (2008) reported a higher saturated fatty acid content, lower monounsaturated fatty acid content, and similar polyunsaturated fatty acid content in ground beef and strip steak samples from grass-finished steers compared to grain-finished steers. Similarly, Duckett et al. (2009) determined that *Longissimus dorsi* steaks from grass-finished steers had a lower percentage of MUFA and tended to have a higher percentage of SFA. Contrary to these reports, Rule et al. (2002) and Nuernberg et al. (2005) stated that grass-finished cattle had greater PUFA concentration than grain-finished cattle. The differences in saturated fatty acid concentration were attributed to a greater concentration of stearic acid (18:0). Additional fatty acids affected by

finishing system include mysteric acid (14:0), pentadecanoic acid (15:0), and palmitic acid (16:0); however, results have not been consistent between studies (Williams et al., 1983; Rule et al., 2002; Leheska et al., 2008; Duckett et al., 2009). Greater oleic acid (18:1) content in grain-finished beef has been credited for the increased MUFA concentration (Williams et al., 1983; Leheska et al., 2008; Duckett et al., 2009). Stearoyl-CoA desaturase (SCD), an enzyme responsible for the desaturation of stearic acid to oleic acid, has been attributed to the increased oleic acid content of beef from grain-finished cattle (Duckett et al., 2009). Researchers determined that SCD activity is up-regulated in animals on a concentrate based diet (Chung et al., 2007). Leheska et al. (2008) and Duckett et al. (2009) found that grass-finished cattle had greater omega-3 content than grain-finished cattle, while omega-6 content did not differ as a result of finishing system. Grasses have higher omega-3 content than corn or other concentrate feed sources leading to the difference in omega-3 values.

Trans-fatty acid content can vary due to effects of ruminal biohydrogenation. Trans-10 octadecenoic acid concentration is higher in grain-finished cattle. The increased trans-10 octadecenoic acid concentration was attributed to high-energy diets favoring the trans-10 biohydrogenation pathway (Duckett et al., 2009). Trans-11 vaccenic acid and cis-9, trans-11 conjugated linoleic acid (CLA) concentrations were higher in beef of grass-finished cattle compared to beef of grain-finished cattle (Leheska et al., 2008; Duckett et al., 2009). However, there is a large amount of variation in CLA content within finishing system and region (Duckett et al., 2009). Research indicates that cholesterol content of grass-finished and grain-finished cattle is similar (Leheska et al., 2008; Duckett et al., 2009).

In order to clearly understand the impact that differences in fat content may have on human health, it is essential to compare them on a gravimetric basis. For ground beef, consumers

should be informed that 85% lean from grass-finished cattle and 85% lean from grain-finished cattle have the same total fat content. In addition, further research must be conducted to determine if differences in fatty acid profile can have an impact on human health.

Quality Grade

Marbling plays an essential role in the chemical composition and eating quality of beef products. Intramuscular fat is directly related to the USDA Quality Grade of beef. As a result, Quality Grade increases with increases in marbling score or intramuscular fat content. It is well understood that as quality grade increases, percent fat increases and percent moisture decreases. Brackebusch et al. (1991) conducted a study to determine the effects of marbling score on percent moisture, protein, and fat in the following 15 muscles: : *Semitendinosus, Adductor, Semimembranosus, Supraspinatus,* gluteal group*, Rectus femoris, Triceps brachii,* deep pectoral*, Biceps femoris, Longissimus dorsi, Psoas major, Infraspinatus, Rectus abdominis, Serratus ventralis,* and *Spinalis*. The study determined that marbling had an effect on the percentage concentration of fat and water in 15 of the muscles and percentage concentration protein was different in 9 muscles (Brackebusch et al., 1991). Miller et al. (1981) reported that increased total lipid content was due to increased total triglyceride content. A positive linear relationship between longissimus marbling score and percent fat, as well as, a negative linear relationship between longissimus marbling and percent moisture has been reported in 15 different muscles (Brackebusch et al., 1991). Studies have reported varying effects on percent moisture and percent ash as a result of Quality Grade (Wulf et al., 1994; Smith et al., 2011).

Quality Grade can have an effect on separable lean and fat. Ramsey et al. (1962) determined in beef carcasses that separable lean decreased and separable fat increased with increasing quality grade. Contrary to this study, Wahrmund-Wyle et al. (2000) determined that quality grade had no effect on the fat content of separable lean. Fatty acid content may be

impacted by quality grade in beef cuts. Harris et al. (1991) determined that the variation in fatty acid profile due to quality grade was significant in fourteen different beef retail cuts. The fatty acids most affected by quality grade were oleic acid (18:1) and palmetoleic acid (16:1), while stearic acid (18:0) and mysteriolic acid (14:1) were the least impacted by quality grade.

Sex Class

Brackebusch et al. (1991) determined that, for heifer and steer carcasses, fat percentage did not differ in 15 different muscles. Percent moisture differed in two (*Psoas major* and *Triceps brachii*) out of the 15 muscles evaluated. Contrary to this study, Keane and Drennan (1987) reported that steer carcasses had a higher lean and bone proportion and a lower fat proportion than heifer carcasses at equal Yield Grade. Therefore, steers would have a greater amount of free water within a similar cut than heifers. However, Keane and Drennan (1987) did not consider the effect of marbling score on proximate composition. As stated previously, as the fat content of a muscle increases the water content will decrease.

Other researchers have determined that differences occur in fatty acid content as a result of gender. Westerling and Hedrick (1979) reported that subcutaneous and intramuscular fat depots from steer carcasses contained more linoleic and arachidonic acid than fat from heifer carcasses. However, there was no difference in total saturated and unsaturated fatty acid content between the two genders. Eichhorn et al. (1985) determined that muscle and adipose samples from bull carcasses had higher PUFA concentrations, reflected in increased percentages of linoleic acid, linolenic acid, and arachidonic acid, compared to samples from steer carcasses.

Protein

All peptides and proteins are constructed from a set of 20 common amino acids that are covalently linked together in a polypeptide chain. Approximately 17% of human body mass is protein. Functions of proteins include maintaining body structure (e.g., collagen), transportation

(e.g., hemoglobin), facilitating mobility (e.g., actin and myosin), metabolism (e.g., enzymes), regulation (e.g., growth factors, transcription factors), and immune function (e.g., immunoglobins) (McNurlan and Anthony, 2000). Proteins are very diverse in their function; however, collagen, actin, myosin and hemoglobin make up nearly 50% of the human body's proteins. Proteins and amino acids contain substantial amounts of nitrogen (approximately 16%) as compared to other compounds such as amino sugars and nucleic acids.

Throughout life, protein is needed to maintain adequate body protein mass. Health status diminishes and many diseases progress when body protein is lost. Renal, gastrointestinal, and liver diseases, as well as cancer, all are associated with loss of whole body protein resulting in increased mortality. Average daily protein consumption in the United States is 80 grams (Zanovec et al., 2010). In addition to exogenous sources of protein, the body synthesizes and degrades an additional 300 grams of protein each day. The approximately 400 grams of protein that is broken down to amino acids is used to resynthesize approximately 300 grams of body protein. The remaining amino acids are catabolized to provide energy or to form glucose. This process of continually degrading and resynthesizing body protein is termed protein turnover. Protein degradation results in free amino acids that are available for protein turnover, synthesis of non-protein compounds, and serving as intermediates in various metabolic pathways (McNurlan and Anthony, 2000; Stipanuk, 2000).

The 20 amino acids formed from protein degradation that serve as precursors for protein synthesis can be separated into two groups: (1) indispensable or essential, and (2) dispensable or nonessential. Borman et al. (1946) defined indispensable amino acids as, "one which cannot be synthesized by the animal, out of materials ordinarily available to the cells, at a speed commensurate with the demands for natural growth." The nine amino acids that the human body

cannot synthesize are phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, histidine, leucine, and lysine. The human body is capable of synthesizing the following eleven amino acids alanine, arginine, asparagine, aspartate, cysteine, glutamate, glutamine, proline, glycine, serine, and tyrosine. All amino acids consist of an amino group, hydrogen, a side chain or R-group and a carboxylic acid group that are bonded directly to a central carbon atom known as the α-carbon. The R-group of an amino acid dictates additional physical and chemical properties such as size, shape, solubility and polarity.

The metabolic state of an individual determines the human body's demand for various amino acids. Growth, injury or disease may cause an increased demand for an amino acid or a decrease in the capacity of an amino acid to be synthesized. During these scenarios, protein synthesis and protein degradation will be affected in an attempt to keep the body in protein balance. During maintenance, the body is in protein balance and the dietary intake of every amino acid is equal to the losses in digestion, secretion, and metabolism (Stipanuk, 2000). In order to keep a healthy individual in protein balance, the recommended allowance for dietary protein is 0.8 grams per kilogram of body weight per day (IOM, 2005). This calculates to an average of 46 grams and 56 grams of dietary protein per day for women and men, respectively. These needs increase during times of protein accretion, such as growth, pregnancy, lactation, and injury, when protein synthesis is greater than protein degradation.

Protein quality is a result of differences in total protein and amino acid composition, which cause variation in their ability to satisfy the human body‘s metabolic demand for amino acids (Stipanuk, 2000). The WHO (2007) defines protein quality as a measure of protein bioavailability. According to Stipanuk (2000), protein quality is dependent on three attributes: its digestibility, the availability of its amino acids, and the pattern of amino acids making up the protein. Digestibility of a protein is important since only the part of the protein that is digested can contribute to dietary

amino acid requirements (Stipanuk, 2000). Meat has approximately 94% digestibility, whereas whole corn and beans 87% and 78% digestible, respectively (FAO, 1991). Availability refers to the chemical integrity of an amino acid that determines the availability once absorbed into the body (Stipanuk, 2000). The last factor determining the efficiency of protein utilization is the amino acid composition.

Minerals

The human body is incapable of producing minerals, so minerals must be consumed as a part of the human diet. Minerals are naturally occurring, inorganic substances. Minerals are divided into two categories: macro minerals and micro minerals. Macro minerals are needed by the body in large quantities. Inadequate consumption of minerals can result in severe deficiencies leading to short-term and/or long-term health complications.

Iron

The most obvious function of iron is its structural role in hemoglobin and myoglobin. Iron is a constituent of the hemoglobin and myoglobin proteins which are involved in the transport and metabolism of oxygen. Both heme iron and non-heme iron are required for enzymes important in the electron transport chain such as NADH dehydrogenase and succinate dehydrogenase. Iron also is important in amino acid catabolism. Iron deficiency is the most the most widespread deficiency in the world and can impact motor and mental development in children.

The recommended dietary iron intake is 12 milligrams for women and 8 milligrams for men aged 19 to 50 years (NAS, 2006). Beef is the third best source of iron in the American diet providing 1 to 3 milligrams of iron per 100 grams of beef (Cotton et al., 2004). Chicken and turkey contain only 60 to 70% as much iron as beef. Soybeans, black beans, kidney beans, and pinto beans contain more iron (3 to 5 grams per 100 grams) than beef, however, the absorption of

this non-heme iron is low (Brewer and Hatch, 2010). Non-heme iron is absorbed at a rate of 2 to 20%, while heme iron absorption ranges from 15 to 35% (British Nutrition Foundation, 1995). The presence of lean meat in the diet in combination with beans and dark leafy greens can help improve the absorption of non-heme iron by up to three fold (Brewer and Hatch, 2010).

Selenium

Selenium is an essential micronutrient for humans due to its role as a cofactor for reduction of antioxidant enzymes, such as glutathione peroxidases. Glutathione peroxidases are responsible for removing reactive oxygen species. The recommended dietary allowance of selenium for adults ages 19 -50 years is 55 micrograms per day (NAS, 2006 -12). Beef is the second best source of selenium in the American diet (Cotton et al., 2004). Animal protein sources contain between 19 – 48 micrograms selenium per 100 grams (USDA-ARS, 2011). Non-animal protein sources, such as black beans and pinto beans contain less than 2 micrograms selenium per 100 grams (USDA-ARS, 2011).

Zinc

Zinc is required for the activity of many enzymes and metaloenzymes in the human body. Protein digestion enzymes such as aminopeptidase, carboxypeptidase A and B, and neutral protease all require zinc. Zinc is present in enzymes responsible for alcohol metabolism, bone formation, glycolysis, heme biosynthesis, boosting the immune system, and collagen breakdown. Zinc has a non-enzymatic role in proteins relating to regulation of genes. “Zinc fingers” are necessary for the transcript factor to bind to DNA and stimulate the transcription of a gene. The most common symptom of zinc deficiency is retarded growth due to the disruption of insulin-like growth factor I. While zinc plays an important role in many of the body’s functions, the recommended dietary intake for zinc is very low at 8 milligrams per day for women and 11

milligrams per day for men 19-70 years of age (NAS, 2006). Zinc is widely available in the food supply; the richest sources are oysters, liver, beef, dark poultry, meat, veal, and crab (Brewer et al., 2010). Welsh and Marston (1982) estimated that 43% of dietary zinc is provided by meat, poultry, and fish, and 25% is provided by milk, cheese, ice cream, and eggs. Beef is the best source of zinc in the American diet (Cotton et al., 2004). Beef and lamb contain 3.3 and 5.4 milligrams zinc per 100 grams, respectively, which is nearly 33 to 50% more zinc than chicken or turkey contain (1 to 2 milligrams per 100 grams) (USDA-ARS, 2012).

Vitamins

Vitamins are organic compounds or hormones required by an organism for normal growth and development. Vitamins are classified as either water-soluble or fat-soluble. In humans, vitamins A, D, E, and K are considered fat-soluble. These vitamins are absorbed in the gastrointestinal tract through the aid of lipids and are more likely to accumulate in the body. Water-soluble vitamins include B vitamins and vitamin C. Water-soluble vitamins are readily excreted from the body; thus, consistent intake is important.

B12

Vitamin B12 is needed for fatty acid metabolism in the formation of the myelin sheath around nerves and for the formation of healthy red blood cells. The recommended dietary intake for Vitamin B12 is 2.4 µg per day for both men and women (NAS, 2006). Beef is the best source of Vitamin B12 in the diet providing 1.2 to 2.6 µg per 100 grams (Cotton et al., 2004). Beef provides four times the amount of Vitamin B12 as chicken and turkey (0.4 µg per 100 g) (USDA-ARS, 2012). Vegetable protein sources lack Vitamin B12 resulting in concerns of B12 deficiency in vegans.

Riboflavin

Riboflavin or Vitamin B2 is essential for the synthesis of flavocoenzymes (FAD, FMN) which function in oxidation-reduction reactions involved in the catabolism of glucose, fatty acids, ketone bodies, and amino acids. The RDA of riboflavin is 1.1 mg/day for women and 1.3 mg per day for men ages 19 to 50 years (NAS, 2006). Red meat and poultry provide 0.13 to 0.42 mg per 100 g (USDA-ARS, 2012). Brown rice provides much more riboflavin; 1.53 mg per 100 g (USDA-ARS).

Niacin

Niacin is essential for the formation of pyridine nucleotide coenzymes that function in oxidation-reduction reactions involved in the catabolism of glucose, fatty acids, ketone bodies, and amino acids (Stipanuk, 2000). The RDI for adults 19 to 50 years of age is 14 mg per day for women and 16 mg per day for men (IOM, 2005). Lean meat, fish, and peanuts are the best sources of niacin providing 6.3 to 13.4 mg per 100 grams (USDA-ARS). Vegetable sources of protein (soybeans, black beans, pinto beans) provide much less niacin (0.3 to 0.6 mg per100 g) than red meat and poultry (USDA-ARS).

Role of Red Meat in a Healthy Diet

In epidemiological studies, red meat is often targeted as a contributing factor to obesity, coronary heart disease, and Type-2 diabetes. More recent experimental studies have reported the benefits of animal protein in a diet to help manage or prevent obesity, coronary heart disease, type 2 diabetes, and sarcopenia (Leslie et al., 2002; Campbell, 2007; Layman et al., 2008; Campbell and Tang, 2010; Phillips, 2012). The following is a brief review of the role of protein in the diet to help manage and prevent chronic diseases.

Obesity is one of the most serious public health concerns in the 21st century. Obesity increases the likelihood of comorbidities including hypertension, type 2 diabetes, dyslipidemia, coronary heart disease, stroke, cancer, osteoarthritis, sleep apnea, and respiratory problems. The incidence of obesity, which is defined as a body max index > 30 kg/m^2, has drastically increased since 1976 (CDC, 2008) from 15% of Americans to over 33% (CDC, 2008). In addition, over 66% of Americans are classified as overweight (> 25 kg/m^2) (CDC, 2008). The two primary causes of obesity are 1) excessive energy intake and 2) insufficient physical activity. Both of these factors must be considered when determining a proper intervention for obesity. Recent research has shown the benefits of increasing the proportion of dietary protein to help reduce total energy intake (Leslie et al., 2002; Melanson et al., 2003; Campbell and Tang, 2010).

Compared to carbohydrate and fat, protein is a more satiating macronutrient. Both short-term and long-term experimental studies have revealed that individuals consuming a high protein diet (30% of total energy) had greater satiety during postprandial periods as well as during meals (Skov et al., 1999; Noakes et al., 2005; Weigle et al., 2005). These studies suggested that a moderate increase in dietary protein at the expense of carbohydrate and fat may promote satiety which, in turn, increase weight loss through reduced energy consumption.

High protein diets increase total weight loss and increase the percentage of fat loss (Skov et al., 1999; Noakes et al., 2005; Weigle et al., 2005). Both short-term (6 months) and long-term (12 month) studies have shown that fat loss is greatest in individuals consuming a high protein diet (25% of total energy) compared to a moderate protein diet (12% of total energy) (Weigle et al., 2005). Individuals on a slightly higher protein diet are more successful at maintaining a lower weight than individuals on a lower protein diet (Weigle et al., 2005). The weight loss and negative energy balance that is achieved in these studies is probably due to lower total energy

intake as a result of enhanced satiety. A moderately higher protein, energy-controlled diet may represent a more practical diet change that can be maintained over longer periods of time.

Obesity, along with hypertension, physical inactivity, family history, smoking, abnormal blood lipid levels, diabetes, abdominal obesity, and over-consumption of alcohol are all risk factors for cardiovascular disease (CVD). Cardiovascular diseases affect one in three American adults, and are the leading cause of mortality (Lloyd-Jones et al., 2009). Numerous epidemiological studies have linked red meat consumption to an increased risk of CVD due to total fat, SFA, trans fat, and cholesterol intake. Due to these studies and media, many consumers believe that it is important to decrease their consumption of red meat due to the perception that red meat is always high in SFA and cholesterol. Currently, there is no direct evidence that lean beef consumed as a part of a heart-healthy diet increases the risk of CVD. A recent meta-analysis showed that beef consumption decreased total cholesterol, triglyceride, and LDL cholesterol levels to similar levels as diets consisting of fish or poultry (Maki et al., 2012). Due to a collective effort starting with the beef producer through the merchandiser in terms of breeding, management, and trimming decisions; beef has become leaner over the past two decades (McNeill et al., 2012). A sirloin steak purchased today on average contains 34% less total fat and 17% less saturated fat than a sirloin steak from 1980 (McNeill et al., 2012).

Current dietary guidance to reduce fat intake recommends consumption of foods such as lean meats and poultry, fruits and vegetables, whole grains, legumes, nuts and seeds, low-fat dairy products, and fish. These nutrient-dense foods are encouraged at the expense of calorie-dense, nutrient-poor food choices. Most importantly, individuals should strive to consume a diet that is balanced in all food groups to ensure nutrient adequacy and energy balance.

Lean beef is an example of a nutrient-dense food that should be included as a part of a balanced diet. Lean beef contains less than 10 g of total fat, less than 4.5 g of SFAs, and no more than 95 mg cholesterol per 3-oz. serving. In addition, 54% of the fatty acids in lean beef are MUFA or PUFA. The Dietary Guidelines (USDA, 2010) for Americans encourage substituting MUFA and PUFA for SFAs in the diet. One-third of SFA in beef is stearic acid, which has been shown to have a neutral effect on blood cholesterol. Beef fat also contains trans fatty acids that do not increase the risk for CVD and may have a positive effect on health.

When consumed as a part of a lipid-lowering diet, lean beef has effects on serum lipid levels that are similar to those of chicken or fish (Davidson et al., 1999; Hunninghake et al., 2000; Scott et al., 2010). Scott et al. (2010) compared blood lipid responses of a heart healthy diet (<30% total fat, <10% SFA, and <300 mg cholesterol) made of lean beef and chicken/fish or chicken in men with hypercholestermia. The study revealed similar reductions in blood total cholesterol, LDL, HDL, and triglyceride levels for each diet (Scott et al., 2010). Most recently, a 6 week randomized cross-over feeding trial compared the blood lipid levels of men and women consuming either a Healthy American Diet (HAD), Dietary Approaches to Stop Hypertension diet (DASH), Beef in an Optimal Lean Diet (BOLD), and BOLD+ diet (Roussell et al., 2012). The researchers reported that the DASH, BOLD, and BOLD+ diets all reduced serum triglyceride, total cholesterol, and LDL at similar levels (Roussell et al., 2012). These studies highlight the effectiveness of a beef-containing diet to improve the blood lipid profiles, thus helping to lower the risk for CVD.

Type-2 diabetes is a risk factor for CVD. The prevalence of diabetes mellitus is increasing worldwide. Of the estimated 171 million people with diabetes in 2000, 90% had Type-2 diabetes mellitus (Aune et al., 2009). Type-2 diabetes mellitus occurs as a result of

decreased beta-cell sensitivity to insulin or decreased insulin production. Established risk factors for Type-2 diabetes include being overweight or obese and physical inactivity. In addition, recent evidence supports the role of dietary factors in the development of Type-2 diabetes mellitus (Aune et al., 2009). Cohort studies have revealed that a Western dietary pattern has an associated risk of Type-2 diabetes mellitus; however, these studies were not able to identify which components of the dietary pattern may increase the risk of type 2 diabetes (Aune et al., 2009). Aune et al. (2009) conducted a meta-analysis comparing the relative risk of Type-2 diabetes mellitus when consuming high verses low intake for total meat, red meat, and processed meat. The study revealed that total meat consumption does not increase the risk of Type-2 diabetes, while red meat (21%) and processed meat may increase the risk of Type-2 diabetes by 21% and 41%, respectively. One potential downfall to this meta-analysis is that not all of the studies adjusted for physical activity, obesity, and being overweight which are risk factors for Type-2 diabetes mellitus. Additional, epidemiological studies have shown varying results on the consumption of red meat and the risk of type 2 diabetes (van Dam et al., 2002; Song et al., 2002; Pan et al, 2011). Some studies indicated an increased risk for diabetes with the consumption of total meat, red meat, and processed meat; while other studies have only indicated that consumption of processed meats (often are higher in fat) are associated with an increased risk for diabetes (van Dam et al., 2002; Song et al., 2004; Pan et al., 2011).

Contrary to these studies, short-term feeding trials reported that consumption of high protein, low carbohydrate diets are beneficial in individuals with Type-2 diabetes. Krezowski et al. (1986) indicated that the consumption of a test meal consisting of 50 g of protein (lean beef) resulted in a decreased plasma glucose and insulin response compared to a test meal containing 50 g of carbohydrate. In a clinical trial, obese patients consuming a high protein diet for 14 days

had decreased hemoglobin A1C levels, improved insulin sensitivity, and normalized glucose levels (Boden et al., 2005). Additional studies have further determined that a high protein/low carbohydrate diet decreased fasting plasma glucose and A1C levels. Dietary protein also appears to stimulate insulin release which may be important for long-term maintenance of muscle mass and bone health (Layman et al., 2008). One possible explanation for decreased plasma glucose levels and decreased HA1C levels is the low glycemic index of animal derived protein sources. Animal derived protein sources have a glycemic index of zero which decreases the total glycemic load an individual consumes in a day. In addition, studies have shown that high protein diets result in reduction of weight and food energy (Leslie et al., 2002; Campbell and Tang, 2010), both of which improved blood glucose control and decreased fasting glucose concentrations in individuals with or without Type-2 diabetes (Layman et al., 2008).

Traditionally, dietary protein recommendations have been based on preventing deficiency versus promoting optimal health. The recommended dietary allowance (RDA) is defined as the amount of a particular nutrient that would satisfy the needs of 98% of the specified population (IOM, 2005). Currently, the RDA for protein is set at 0.8 g per kg of body weight per day. The RDA is not an individual requirement for protein as individual needs may be higher or lower depending upon the circumstance (IOM, 2005). Protein intake also can be measured in the acceptable macronutrient distribution range (AMDR) which is 5-35% of calories, depending on age. Following a dietary pattern as described by the Dietary Guidelines for Americans (USDA, 2010), the estimated intake of protein should be from 17 to 21% of total calories.

Labeling of Red Meat

The following is adapted from the Department of Agriculture, Food Safety and Inspection Service, Federal Register on 9 CFR Parts 317 and 381; Final Rule, unless otherwise stated.

In an effort to continue to provide the most relevant and recent nutrient data to consumers, the USDA continues to update nutritional labeling regulations and the USDA Nutrient Database for Standard Reference (SR). These resources, along with the Dietary Guidelines for Americans, can be used to help ensure consumers have all the information necessary to purchase foods for a nutritionally complete and balanced diet. Since meat products vary in lean content, it is essential to provide nutritional labels for meat products so consumers can assess levels of nutrients and make educated choices.

Before 2012, retailers could voluntarily include nutritional facts labels on their fresh meat products. With the implementation of the Nutrition Labeling of Single-Ingredient Products and Ground or Chopped Meat and Poultry Products; Final Rule in March 2012 it became mandatory to include the nutritional facts label on specified cuts of meat. The Food Safety Inspection Service (FSIS) determined that major cuts of single-ingredient, raw meat and poultry products that do not bear nutrition information on their labels or on point-of-purchase materials will be misbranded under section 1(n) of the Federal Meat Inspection Act (FMIA) (21 U.S.C. 601(n) (1)) and section 4(h) (1) of the Poultry Products Inspection Act (PPIA) (21 U.S.C. 453(h) (1)). To enforce this, the FSIS has amended the Federal meat and poultry products inspection regulations to require nutrition labeling of the major cuts of single-ingredient, raw meat and poultry products, including ground products, on labels or at point of purchase, effective March 1, 2012.

The major cuts of single-ingredient, raw meat products, according to 9 CFR 317.344, are listed in Table 2.1. Numerous trade organizations believe that the list of major cuts is outdated and does not reflect many of the common cuts currently purchased at retail. However at this time, FSIS has indicated that they are not going to change the list of major cuts.

Headings that are required for labeling include “Nutrition Facts,” “Amount per Serving,” and “% Daily Value.” Nutrients that must be listed in the “Nutrition Facts” table include

“Calories,” “Total Fat,” “Cholesterol,” “Sodium,” “Total Carbohydrate,” “Protein,” “Dietary Fiber,” “Sugars,” “Total Fat,” “Saturated Fat,” and “Trans Fat.”. “Vitamins” and “Minerals” are included as a percent of the recommended daily intake (RDI) for a 2000 kcal diet. The vitamins and minerals that must be listed include (in order) Vitamin A, Vitamin C, Calcium, and Zinc. Monounsaturated fat, PUFA, and potassium may voluntarily be included in the Nutrition Facts table. The Atwater coefficients for protein, carbohydrate, and fat (4, 4, and 9, respectively) are used to calculate calories. Additional mandatory items on the label include the name of the product, a list of ingredients, net quantity of contents, and an official inspection legend and number of official USDA establishment.

Products exempt from the nutrition labeling of single-ingredient products and ground or chopped meat and poultry products final rule include:

- products intended for further processing bearing no nutritional claim,
- products not intended for consumers bearing no nutritional claim,
- products less than 0.5 oz. and individually packaged bearing no nutritional claim,
- products that are custom slaughtered or prepared,
- products intended for export,
- products that are ―non-major cuts of single-ingredient, raw products,
- ground or chopped products that qualify for small business exemption,
- products ground or chopped upon consumer request,
- ground or chopped products in packages of total surface area of 12 square inches or less, and
- ground product produce by small business bearing no nutritional claim other than percent fat and percent lean.

Small business exemptions are only available for chopped or ground products. Small businesses are defined as retailers who have annual gross sales of not more than $500,000 or have annual gross sales of foods or dietary supplements of not more than $50,000. Other qualifications for the small business exemption include those businesses that employ less than an average of 100 full-time employees and fewer than 100,000 units of that product are sold in the United States in a 12-month period.

The FSIS will conduct random product sampling and nutrient analysis of ground and chopped products. Major cuts of single-ingredient, raw products that include a nutrition facts label based on the USDA's National Nutrient Data Bank or USDA's National Nutrient Database for SR will not be sampled since this data is already USDA validated.

In addition, according to 9 C.F.R. 317.362, meat also can be marketed as "Lean" or "Extra Lean." Items described as "lean" must contain less than 10 grams of total fat, 4.5 grams or less of saturated fat, and less than 95 milligrams of cholesterol per reference amount and per 100 grams. The term "extra lean" can be used to describe products that contain less than 5 grams of fat, 2 grams or less of saturated fat, and less than 95 milligrams of cholesterol per reference amount and per 100 grams. Additional certification of the Heart Healthy Checkmark from the American Heart Association can be used on product that contains less than 5 grams of fat, 2 grams or less of saturated fat, less than 0.5 grams of trans fat, and less than 95 milligrams of cholesterol per reference amount and per 114 grams.

Development of USDA Beef Grading Standards

The Official United States Standards for Grades of Carcass Beef (USDA, 1997) are used to separate beef carcasses into categories based on differences in quality and composition to aid in the marketing of beef. Tentative United States grading standards were originally developed in

1916. In 1925, through public hearings, sectors of the meat industry were allowed to provide their comments and suggestions for potential changes to the grading standards. After revisions were made, in 1926, the Secretary of Agriculture declared the standards the Official United States Standards for Grades of Carcass Beef which were to be utilized when voluntary beef grading began in 1927. Since 1926, the grading standards have undergone 12 revisions to more accurately represent the current beef market and practices. The most recent revisions occurred in 1997 in an effort to improve the uniformity and consistency within the Choice and Select grades. The Select grade was confined to only A maturity carcasses and B maturity carcasses had to have a minimum marbling score of Modest to quality for Choice. Due to these revisions, B maturity cattle with a marbling score below Modest qualify for the U.S. Standard grade.

Official Quality Grades (QG) and Yield Grades (YG) are assigned to carcasses separately to predict the eating quality of the lean and estimate carcass cutability, respectively (USDA, 1997). United States Department of Agriculture employees determine and accept QG and YG, independent of the producers and packers. Determination of QG and YG is a voluntary service paid for by the packer.

Official Quality Grade is determined based on the following factors: sex classification, lean and skeletal maturity, marbling score, and firmness of the *Longissimus dorsi* muscle. Separate Quality Grade standards have been developed for (1) heifer, steer, and cow beef and (2) bullock beef. Heifer and steer carcasses have eight quality grade designations – Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner. These same designations, except for Prime, can be applied to cow carcasses. The marbling score is determined based on the percent intramuscular fat (marbling) in the longissimus dorsi. Marbling score in combination with

skeletal maturity, sex classification, and firmness of the *Longissimus dorsi* muscle, is utilized to determine the official Quality Grade.

The physiological maturity of a beef carcass is determined by evaluating the size, shape, and ossification of the bones and cartilage, as well as the color and texture of lean (USDA, 1997). Ossification changes generally begin in the posterior portion of the vertebral column and progressively move anterior over time. The amount of ossification of the cartilaginous buttons on the thoracic vertebrae at the posterior end of the forequarter is often referred to in the grading standards. Rib bone size and shape also is important for evaluating differences in maturity. As an animal matures, the color and texture of the lean also undergoes changes. As an animal ages, the lean will gradually become coarser and darker red. The overall maturity is determined based on both skeletal and lean maturity. If skeletal and lean maturities differ, more emphasis is placed on the skeletal maturity so that overall maturity cannot be more than one full maturity group different than skeletal maturity.

Overall maturity has five designations: A, B, C, D, and E. The youngest carcasses that have distinct sacral vertebrae separation, no ossification of the lumbar and thoracic vertebrae, slightly flat ribs, soft and very red chine bones, light grayish red lean color, and very fine lean texture are classified as A maturity. B maturity carcasses exhibit completely fused sacral vertebrae, nearly completely ossified lumbar vertebrae, some evidence of ossification of the thoracic vertebrae, slightly wide and flat ribs, slightly soft and red chine bones, light red to slightly dark red lean color, and fine lean texture. The most mature carcasses are classified as E maturity and exhibit completely fused sacral vertebrae, completely ossified lumbar vertebrae, thoracic vertebrae that are barely visible, wide and flat ribs, hard and white chine bones, dark red to very dark red lean color, and coarse lean texture.

Based on the current standards for Quality Grade, within a specific grade, as overall maturity increases the amount of marbling required also increases. This occurs in all maturity classifications, except for A maturity and within the Choice grade in B maturity.

Chronological Age and Physiological Maturity

Previous studies have not established a definite relationship between physiological change and chronological age of an animal. It is known that as an animal ages, cartilage ossification occurs leading to characteristics of advanced skeletal maturity in those carcasses. The USDA Maturity Classifications (USDA, 1997) were established based on the expected skeletal maturity that an animal should exhibit over a range of chronological ages. Grain-finished cattle under 30 months of age will typically produce A maturity carcasses; however, 3 to 14% of these grain-finished animals will produce carcasses that will be classified as B maturity or older (Tatum, 2011).

Data originally presented by O'Connor et al. (2007) and reanalyzed by Tatum (2011) indicated that most (96.7%) grain-finished cattle between 12 to 24 months of age will produce an A maturity carcass. As animal age increases to 18 months of age, the probability of producing a B maturity or older carcass increases. For cattle between 22 to 24 months of age, the incidence of a B or C maturity carcass increases to 9.1% and 3.1% as compared to 1% and 0.001% for cattle 18 months or older. These data suggest that chronological age is not the only factor that impacts skeletal maturity.

Due to exogenous and endogenous hormones, some carcasses exhibit skeletal maturity characteristics that are more advanced than their chronological age (Tatum, 2011). Estrogen is a potent activator of skeletal ossification causing females to exhibit more advance skeletal characteristics than their male counterpart (Field et al., 1996). As a result of natural estrogen

levels, heifers typically exhibit increased ossification of the cartilage at an earlier age (Field et al. 1996). Due to an increased amount of endogenous estrogen, heifers produce beef carcasses that are more likely to be classified as B maturity or older than carcasses produced by steers that are the same chronological age (Tatum, 2011). Tatum (2011) analyzed skeletal maturity data from heifer (n = 3095) and steer (n = 3671) carcasses that were 16 to 27 months of age and reported that skeletal maturity classification increased quicker in heifer carcasses than in steer carcasses. This trend was especially prominent in heifers harvested after 20 months of age. Of the carcasses produced by heifers 21 to 24 months of age, 25% produced B maturity carcasses and 6% produced a carcass with C maturity skeletal attributes, respectively. In steers of the same age, 3% and less than 0.001% produced a carcass with B or C maturity characteristics, respectively. Klindt and Crouse (1990) determined that intact heifers had higher skeletal maturity scores than steers and ovariectomized heifers of the same age.

During pregnancy, estrogen levels dramatically increase (Smith et al., 1973; Hoffman et al., 1976). Between 4-17% of heifers enter the feedlot pregnant (Laudert, 1988; Kreikemeier and Unruh, 1993). Kreikemeier and Unruh (1993) determined that in feedlot heifers, pregnant heifers were more likely to produce a carcass with advanced skeletal maturity traits than a non-pregnant heifer of similar age. Field et al. (1996) found in a study comparing ovariectomized, virgin, and single calf heifers (31 – 35 months of age) that skeletal maturity traits were different. Overall skeletal maturity attributes progressively increased from spayed to once-calved heifers (Field et al., 1996). Single calf heifers produced more C maturity carcasses than the ovariectomized heifers even though the single calf heifers were only 32 days older on average. Over three-fourths (77.8%) of the single calf heifers were classified as B maturity or older, as compared to 37.5% and 5.6% for the ovariectomized and virgin heifers, respectively. Waggoner

et al. (1990) reported once-calved heifers were more likely to exhibit advanced skeletal maturity traits than open heifers. This suggests that skeletal maturity differences remain after pregnancy. These studies confirmed that pregnancy increased skeletal maturity scores at a faster rate than chronological age (Bond, 1986; Waggoner et al., 1990; Field et al., 1996).

Exogenous estrogen may also impact skeletal maturity traits. Over 97% of feedlot cattle receive some type of anabolic implants during their lifetime (Tatum, 2006). Anabolic implants are comprised of an estrogen, androgen, or both. Estradial 17-β, estradiol benzoate, and zeranol are active ingredients in estrogenic implants. The active ingredient in androgenic implants is trenbolone acetate. Similar to endogenous estrogen, increased exogenous estrogen levels as a result of implants also can increase skeletal maturity (Apple et al., 1991; Paisley et al., 1999; Roeber et al., 2000; Reiling and Johnson, 2003).

Apple et al. (1990) compared Holstein steers of the same chronological age and reported implantation with an estradiol increased skeletal and overall maturity of carcasses compared to not using an implant or using an implant containing only trenbolone acetate. Paisley et al. (1999) determined that steers administered an estradiol-containing implant had more advanced skeletal maturity characteristics. Numerous other researchers have determined that implanting steers or heifers with estradiol-containing implants will lead to carcasses exhibiting more advanced skeletal maturity traits (Turner et al., 1981; Foutz et al., 1997; Paisley et al., 1999; Roeber et al., 2000; Reiling and Johnson, 2003). Effects of implants on skeletal maturity traits appear to be greater when cattle receive repetitive implants over their lifetime (Platter et al., 2003; Scheffler et al., 2003).

The effect of implants on skeletal maturity is insignificant for a majority of the U.S. cattle supply since most cattle are harvested at less than 20 months of age (O'Connor et al., 2007).

However as animal age increases beyond 20 months, or as the number of successive implants increase, there may be larger impact on the number of cattle being classified as B maturity or older. Tatum (2011) reported that implants have the most dramatic effect on skeletal maturity traits after 21 months of age, especially in heifers.

Another source of exogenous estrogen could be naturally produced by fungi (mycoestrogens) and plants (phytoestrogens). When consumed, estrogens in these natural sources can bind to the estrogen receptor and mimic the effects of endogenous estrogen. This could potentially lead to advanced skeletal maturity characteristics in heifers and steers.

Collagen Development

Fibroblasts and myocytes form collagen to serve as a structural support system for the cellular components of muscle (McCormick, 1994). Through transcription and translation, pro-collagen is formed and later modified to make tropocollagen. Three alpha-strands of tropocollagen combine to form a single helix of collagen. The stability of collagen, including thermal stability, is greatly impacted by the degree of covalent crosslinking. In young animals, crosslinking occurs through Schiff base reactions that form reducible, heat labile crosslinks. These crosslinks will gelatinize when properly cooked so that the effect of collagen on meat tenderness is reduced. As animal ages, condensation of the crosslink occurs and non-reducible, heat stabile crosslinks form. The heat-stable crosslinks are resistant to solubilization and serve as a major contributor to increased toughness in meat products from more mature animals (Goll et al., 1963; Zinn et al., 1970). Cross (1973) linked the amount and solubility of collagen to age such that as the amount of soluble collagen decreases as an animal increases in physiological age. The advancements in physiological maturity can be detrimental to overall eating quality, especially tenderness.

Collagen and Meat Tenderness

Meat tenderness is determined by two factors: 1) the nature and state of the contractile protein and 2) the content and properties of the connective tissue (Dutson, 1974). The content and properties, such as crosslinking, of connective tissue are influenced by an animal's age (McClain, 1977). However, the diet of an animal may influence the amount of crosslinking regardless of age. Research has determined that cattle fed high energy diets for at least 28 days before slaughter generally experience rapid growth and protein turnover (Moody, 1976). During periods of rapid growth, protein synthesis will increase causing new collagen to be formed (Millward and Waterlow, 1978). The newly synthesized collagen will have less heat-stable crosslinks leading to an increase in solubility (McClain, 1977) and overall tenderness of the meat product (Hill, 1966). Cattle fed a high energy diet even for a short period of time before slaughter will produce beef that has improved beef tenderness due to the rapid turnover of collagen (Zinn et al., 1970; Campion et al., 1975; Koch et al., 1976).

Schnell et al. (1997) reported that cows fed a high energy diet for at least 56 days before slaughter had increased sensory tenderness scores, increased soluble collagen percent, and similar amounts of total collagen and Warner-Bratzler shear force values compared to cattle not fed a high energy diet. In a study comparing 10-year-old cows fed a low energy or high energy diet, Miller et al. (1987) found that total collagen amount remained the same between groups. Cows that were fed a high energy diet had an increased percentage of soluble collagen, lower Warner-Bratzler shear force values, and improved sensory tenderness scores (Miller et al., 1987b). Cranwell et al. (1996) determined that cows fed a high energy diet 28 days before slaughter had similar total collagen amount and increased percent heat soluble collagen compared to cows not fed a high energy diet. Total collagen amount should remain constant

among age groups because additional collagen must be synthesized in proportion to total lean synthesis; however, newly synthesized collagen will have fewer crosslinks (Cranwell et al., 1996).

Similar research has been conducted on younger animals. Aberle et al. (1981) conducted a study comparing tenderness and eating quality characteristics of steaks from steers feed either a low energy diet or a high energy diet before slaughter. Steaks from steers fed a low energy diet had increased Warner-Bratzler shear force values, decreased sensory tenderness, juiciness, and flavor scores, and decreased collagen solubility (Aberle et al., 1981). Wu et al. (1981) conducted a similar study and determined that collagen content was similar between cattle fed a low energy diet verses those fed a high energy diet. However, cattle fed a high energy diet had increased amounts of soluble collagen due to an increase in the rate of collagen biosynthesis or decreased rate of collagen crosslink formation (Wu et al., 1981). Fishell et al. (1985) determined that steers fed a high energy diet produced steaks with lower Warner-Bratzler shear force values, improved sensory tenderness scores, and increased amounts of soluble collagen. These research studies provided evidence that, when young cattle (under 30 months of age) are provided a high energy diet, objective or subjective tenderness values will not change proportionally with chronological age.

The United States Grading Standards for maturity (USDA, 1997) are partially utilized to explain differences in tenderness as a result of increased chronological age. Previous research studies suggested that USDA A and B maturity classifications may not be justified based on tenderness differences (Tatum et al., 1980; Shackelford et al., 1995b; Hilton et al., 1998). Shackelford et al. (1995) determined in cattle less than 35 months of age that there was no difference in overall tenderness or amount of connective tissue in steaks from A or B maturity

carcasses. Shackelford et al. (1995) reported that there was more tenderness variation within each classification than between maturity classifications. This study suggested that carcass maturity scores increased at a much faster rate than the chronological age indicated by the USDA Grading Standards (Shackelford et al., 1995a). In addition, Tatum et al. (1980) determined in steers fed a high energy diet that overall tenderness, juiciness, and flavor was not different between steaks from A or B maturity carcasses. Hilton et al. (1998) suggested that when specifically focusing on A and B maturity, there were no differences in overall sensory tenderness, Warner-Bratzler shear force values, connective tissue amount, or flavor. In contrast, Smith et al. (1982; 1988) reported that steaks within equal marbling scores from A maturity carcasses had improved tenderness scores than steaks produced from B maturity carcasses. The data presented by Smith et al. (1982 and 1988) that highlighted the variability in tenderness for steaks from B maturity carcasses with less than Modest marbling was used to establish the Official USDA Grading Standards (USDA, 1997). However the previously mentioned studies suggested that fed cattle under 30 months of age, do not experience tenderness variability proportional to variability in skeletal maturity characteristics.

Table 2.1. Major cuts from red meat species requiring mandatory nutritional labeling

Beef	Pork	Lamb	Veal
Chuck, blade roast	Loin, chop	Shank	Shoulder, arm steak
Loin, top loin steak	Loin, country style ribs	Shoulder, blade chop	Shoulder, blade steak
Rib, rib roast large end	Loin, rib chop	Shoulder, arm chop	Rib roast
Round, eye round steak	Spareribs	Rib, roast	Loin chop
Round, top round steak	Loin, tenderloin	Loin chop	Cutlets
Round, tip roast	Loin, sirloin roast	Leg (whole, sirloin half, or shank half)	
Chuck, arm pot roast	Shoulder, blade steak		
Loin, sirloin steak	Loin, top roast boneless		
Round, bottom round steak	Ground Pork		
Brisket (whole, flat half, or point half)			
Rib, steak small end			
Loin, tenderloin steak			
Ground beef without added seasoning			
Ground beef about 17% fat			

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CHAPTER III

NUTRIENT DATABASE IMPROVEMENT PROJECT: SEPARABLE COMPONENTS AND PROXIMATE COMPOSITON OF RAW AND COOKED RETAIL CUTS FROM THE BEEF LOIN AND ROUND

SUMMARY

Beef nutrition research has become increasingly important domestically and internationally for the beef industry and its consumers. The objective of this study was to analyze the nutrient composition of ten beef loin and round cuts to update the nutrient data in the USDA National Nutrient Database for Standard Reference. Seventy-two carcasses representing a national composite of Yield Grade, Quality Grade, sex classification, and genetic type were identified from six regions across the U.S. Beef short loins, strip loins, tenderloins, inside rounds, and eye of rounds (NAMP # 173, 175, 190A, 169A, and 171C) were collected from the selected carcasses and shipped to three university meat laboratories for storage, retail fabrication, and raw/cooked analysis of nutrients. Sample homogenates from each animal were analyzed for proximate composition. These data provide updated information regarding the nutrient status of beef, in addition, to determining the influence of Quality Grade, Yield Grade, and sex classification on nutrient composition.

INTRODUCTION

In today's society, consumers and producers have an increased awareness of the composition and nutritive value of red meat. According to Troy et al. (2011), the food industry is scrutinized more today than it has been in the past due to concerns about labeling, health claims, safety, product composition, and sustainability. Conflicting observational studies have targeted the fat and cholesterol content of beef and tried to link these traits to cancer, heart

disease, and obesity (Micah et al., 2010; Pan et al., 2011). However, Roussell et al. (2011) indicated that the Beef in an Optimal Lean Diet (BOLD) can reduce total and low density lipoprotein (LDL) cholesterol levels. This study, among others, showed the benefits of including lean beef in a healthy diet (Campbell and Tang, 2010; Layman et al., 2005; Roussell et al., 2011). Up-to-date nutrient information for all beef cuts is essential to drive the research process and provide researchers and dietitians with the necessary nutrient information to make conclusive and comprehensive statements regarding lean beef in the diet. In addition, the nutrient information will be used to update nutrition facts labels on retail beef cuts.

While beef nutrition research hasn't been a priority until recently, beef nutritional information has been available for many decades. Since 1926, the USDA has published beef nutrient data in the USDA National Nutrient Database for Standard Reference (SR). The database is utilized worldwide for food composition comparisons (Merchant and Dehghan, 2006). Updating the SR is an ongoing process since animal management and carcass fabrication procedures are constantly improving, new methods of cooking are used, and new value cuts are created. Conducting research to provide relevant beef nutrient data is important so the values can be included on on-package labels for fresh beef and to identify cuts that are classified as 'lean' or 'extra lean' and potentially use them in the newly redesigned school lunch programs or in other institutional dining situations. The overall objectives of this study were to evaluate the effects of carcass characteristics (i.e., USDA Quality Grade, Yield Grade, and sex classification) on retail cut composition, and to compare composition data with data currently available in the SR. To accomplish these objectives, carcasses were identified and 10 retails cuts from the loin and round were used for generation of proximate data and homogenate samples for further nutrient analysis and inclusion in the SR.

MATERIALS AND METHODS

Carcass Selection

Seventy-two beef carcasses from seven different packing plants in six different regions, (Green Bay, WI; Greeley, CO; Dodge City, KS; Tolleson, AZ; Plainview, TX; Omaha, NE; Corpus Christi, TX) of the Unites States were selected to meet the national consist of beef carcasses based on the 2005 National Beef Quality Audit (Garcia et al., 2008). Carcasses were selected to represent the following characteristics: 67% USDA Choice, 33% USDA Select, 50% USDA Yield Grade 2, 50% USDA Yield Grade (YG) 3, 67% steers, 33% heifers; and 12.5% dairy, 87.5% non-dairy. The sampling criteria were restricted to include only A-maturity carcasses and carcasses with appropriate hot carcass weights (299-411 kg). Trained university personnel identified sex classification, genetic type, ribeye area, fat thickness, marbling score, percentage of kidney, pelvic, and heart fat, maturity, and hot carcass weight. Two paired carcasses ("A" and "B") were selected for each sampling criteria to ensure adequate sample amounts to represent all retail cuts. Paired carcasses were matched for degree of marbling (not crossing the grade line) and all other characteristics prescribed in the sampling plan for that particular carcass.

Subprimal Collection

After selection of carcasses, the left and right side of the loin and round (NAMP # 173, 175, 190A, 169A, and 171C) from each carcass were identified and tagged on the interior and exterior of the needed subprimals to assure identification integrity through fabrication. Carcasses were fabricated according to the plant protocol to obtain the following subprimals: beef loin, short loin (NAMP #173); beef loin, strip loin, bone in (NAMP #175); beef loin, tenderloin, full, side muscle off, defatted (NAMP #190); beef round, eye of round (NAMP #171C); and beef,

round, top (NAMP #169A). Subprimals were collected by university personnel who remained on-site during fabrication to help maintain identity of each subprimal. Identity of the original carcass was maintained throughout the entire project. After collection, each subprimal was either individually vacuum packaged or placed in combos and shipped via refrigerated truck to one of the three collaborating universities. Product temperature was verified before loading and upon receipt at each university to ensure that the product was maintained at 0 to 4^{o}C. Upon reaching their final destination, all subprimals were stored individually vacuum packaged in the absence of light at 0 to 4^{o}C until fabrication.

Retail Cut Fabrication

Between 14 to 21 d postmortem, subprimals were fabricated into pre-identified retail cuts (Table A.2). Before fabrication, weights of individual subprimals were recorded to the nearest 0.1 g. During retail cut fabrication, the short loin (NAMP #173) was fabricated into porterhouse steaks and T-Bone steaks. The strip loin (NAMP #175) was fabricated into top loin steaks. The tenderloin (NAMP #190), eye of round (NAMP #171C), and top round (NAMP #169A) were fabricated into steaks and roasts. A prescribed identification plan was used to determine the location of each steak and roast within the respective subprimal to reduce university variation in cutting procedures. After each subprimal was fabricated into retail cuts, the weight of all remaining lean trimmings, fat trimmings, and refuse were measured and recorded to the nearest 0.1 g. On the date of fabrication, retail cuts were individually identified, vacuum packaged, and frozen (-20^{o}C) until cooking or raw dissection.

Short Loin Fabrication

Before cutting individual steaks, the tail on each short loin (NAMP #173) was trimmed to 2.54 cm and the posterior end of the loin was faced. Steaks were cut 2.54 cm thick starting at the

posterior end and moving to the anterior end. External fat on the porterhouse and T-Bone steaks were trimmed to 0.32 cm. On porterhouse steaks, the fat was notched under the tenderloin; however, the tenderloin was not denuded. Tails were trimmed to an external fat thickness of 0.32 cm, and if present, the *Longissimus costarum* remained on each steak. Steaks from the short loin were classified according to width of the tenderloin, which was measured perpendicular to the transverse process. Porterhouse steaks were classified as having a minimum tenderloin width of 3.18 cm, while steaks with a tenderloin width from 1.27 to 3.18 cm were designated as T-Bones.

Tenderloin Fabrication

Before cutting roasts and steaks from individual tenderloins, the full tenderloin (NAMP #190A) was trimmed to a 0 cm external fat thickness and the silver skin was removed. The tail end of the tenderloin was removed at 2.54 cm in diameter. The side muscle was removed from the tenderloin up to the point where it joined with the *Psoas major*. Three center cut steaks, 3.81 cm in thickness, were removed from the center of the tenderloin. The remaining butt and tail sections from the tenderloin were designated as the tenderloin roasts.

Strip Loin Fabrication

Before fabrication, the strip loin (NAMP #175) was faced on the anterior end. Boneless top loin steaks (2.54 cm in thickness) were cut starting at the anterior end and ending at the posterior end. External fat trim levels of 0 cm to 0.32 cm were alternated between steaks. The trim level for the first steak was pre-determined to ensure proper alternation and randomization of trim levels across strip loins. Steaks trimmed to 0 cm external fat thickness did not have a tail while steaks trimmed to 0.32 cm external fat thickness had a 1.27 cm tail. Vein steaks were identified and defined as those steaks with *Gluteus medius* present on both sides of the steak. Vein steaks were weighed, but were not further analyzed in this study.

Eye of Round Fabrication

Before cutting roasts and steaks from each eye of round (NAMP #171C), the subprimal was trimmed to 0 cm external fat thickness and the silver skin on the anterior end of the subprimal was removed. The subprimal was then cut in half and, beginning at the cut surface of each half, three, 1.27 cm thick steaks were cut. The remaining two ends of the subprimal were used as eye-of-round roasts.

Top Round Fabrication

From the top round (NAMP #169A), the cap muscle (*Gracilis*) and the soft side (*Pectinius, Adductor, and Sartorius*) were removed. All exterior fat was trimmed to a 0 cm and the anterior surface was faced before steak cutting. Starting from the anterior side of the top round, four top round steaks, 1.91 cm in thickness, were removed. One top round roast, 5.08 cm in thickness, was cut in the same manner as the top round steaks. The remaining portion of the top round was divided equally into two "wedge-shaped" roasts by making a cut perpendicular to the anterior face of the subprimal.

Cooking of Retail Cuts

Before cooking, retail cuts to be cooked were tempered in a single layer at 0 to 4°C for 24 or 48 h. Upon thawing, each individual cut was blotted to remove any purge, weighed to the nearest 0.1 g, and raw temperature was recorded. No retail cuts from the round were cooked. Two cooking methods were utilized: grilling and roasting.

Grilling

Cuts assigned to grilling were: porterhouse steaks, T-bone steaks, tenderloin steaks, and top loin steaks (0 cm and 0.32 cm). Before grilling, a Salton two-sided electric grill (Model GRP99, Salton Inc., Lake Forest, IL) was pre-heated until a grill surface temperature of 195°C

was reached. For top loin and tenderloin steaks, two steaks were placed on the grill surface and the cooking start time of each was individually recorded. Top loin 0 cm steaks were cooked separately from the top loin 0.32 cm steaks. For the porterhouse and T-bone steaks, each steak was cooked individually. The steaks were flipped after four minutes or when the internal temperature reached 35^{o}C to ensure even cooking. Temperature was monitored using digital thermocouple thermometers and probes (Type J or T Digi-Sense, Cole Parmer, Vernon Hills, IL). Once an internal temperature of 70°C was obtained, steaks were removed from the grill surface and final internal temperature and cooked weight (to the nearest 0.1 g) were recorded. Immediately after cooking, all steaks were placed on wire racks and allowed to chill uncovered at refrigeration temperatures (0 to 4°C) for at least 12 h before cooked dissection.

Roasting

The tenderloin roast was the only cut assigned to roasting. Each individual tenderloin roast was placed in a non-stick anodized aluminum roasting pan with rack (Calphalon Corp. Toledo, OH). A thermocouple probe was inserted into the geometric center of the roast in order to monitor temperature throughout the cooking process (Type J or T Digi-Sense, Cole Parmer). An oven was pre-heated to 160°C and two roasting pans were placed on the center rack once this temperature was achieved. Once an internal temperature of 60°C was obtained, roasts were removed and individual temperature and time of removal were recorded. Metal tongs were used to remove the roast from a roasting pan and place on a wire rack at room temperature. Peak temperature (highest obtained internal temperature, °C) and time of peak temperature, were recorded for each individual roast. After 30 min of rest at room temperature, the weight of the roast was measured and recorded to the nearest 0.1 g. Samples were then allowed to chill uncovered on wire racks under refrigeration (0 to 4°C) for at least 12 h before cooked dissection.

Retail Cut Dissection

Standardized protocols were used for the dissection of raw and cooked retail cuts. Samples were tempered in a single layer at 0 to 4^{o}C for 24 to 48 h (raw samples) or 12 to 24 h (cooked samples). For each sample, the beginning and end times of dissection were recorded. Individual samples were dissected and weights were recorded for initial cut weight, separable lean, refuse, external fat, and seam fat. If the total weight of separable components was not within a specified yield tolerance range (97 to 101%), the sample was removed from the study and replaced with an extra steak from that cut. Samples that were of the same retail cut and came from the same side of an individual animal were combined for homogenization. Seam and external fat from the raw and cooked samples were frozen and homogenized separately.

Dissection of Raw and Cooked Top Loin Steaks (0 cm and 0.32 cm)

Raw and cooked top loin steaks (0 cm and 0.32 cm) were dissected to yield the following components:

- Refuse (waste) – defined as all bone and heavy connective tissue.
- Separable lean – included all muscle, intramuscular fat and any light connective tissue considered to be edible.
- External fat – defined as the adipose tissue located on the outer surface of the cut.
- Seam fat – included all fat deposited between muscles in a cut and may extend to the outer portion of the cut as a result of fabrication. After recording the lip fat weight, the lip fat was added to the seam fat for homogenization.
- Lip Lean – Included all lean from the lip. The lip was defined as the portion ventral to the curvature of the *Longissimus dorsi*.
- Lip fat – Included all fat from the lip region as previously defined.

Dissection of Raw and Cooked T-Bone Steaks, Porterhouse Steaks, Tenderloin Steaks, and Tenderloin Roasts and Raw Top Round Steaks and Roasts and Eye of Round Steaks and Roasts

Raw and cooked T-bone steaks, porterhouse steaks, tenderloin roasts, and tenderloin steaks were dissected to yield the previously described components, excluding lip lean and lip fat.

Retail Cut Homogenization

Due to the sensitivity of B vitamins and potentially other nutrients, and to prevent contamination, homogenization and aliquoting procedures were performed in the absence of direct light and powder-free nitrile gloves were worn. All lean samples were homogenized on the same day they were dissected. Samples of the same retail cut that came from the same side of an individual carcass were combined for homogenization. Following dissection, each retail cut was cut into 2.5-cm^3 pieces and the pieces were submerged in liquid nitrogen until all pieces were completely frozen. A stainless steel spoon was used to transfer the frozen samples into a 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS) and blended to form a finely-powdered homogenate. Each sample was blended for approximately 10 s on low speed (1500 rpm) and 30 s on high speed (3500 rpm). Fat samples were homogenized in a similar manner to the lean samples. All samples were stored at -80^{o}C for nutrient analysis.

Nutrient Analyses

Proximate analysis (percent fat, moisture, protein, and ash) was performed on the homogenized separable lean from each individual carcass. All analyses were performed in duplicate. Proximate analysis was not performed on the raw tenderloin, eye of round, and top round steaks as their nutrient values would be the same as the roast values. Each USDA-ARS

accredited university laboratory was responsible for performing individual carcass proximate analyses on their respective samples.

Moisture Analysis

Moisture analysis was performed using the AOAC oven drying method 950.46 and 934.01 (AOAC, 1995). Approximately 1 g subsamples were weighed out into aluminum tins and allowed to dry for 24 h at 100°C in a forced air drying oven. Percent moisture (% MC) was calculated using the formula: % MC = [(wet weight – dry weight) / wet weight] x 100.

Protein Analysis

Crude protein was determined using the AOAC (2006) Official Method 992.15 which utilized a nitrogen determinator (Leco TruSpec CN or Leco FP-2000; Leco Corporation, St. Joseph, MI and Rapid N cube, Elementar, Hanau, Germany). Percent protein was calculated by multiplying total percentage nitrogen by a factor of 6.25.

Fat Analysis

Total fat was determined using a variation of the chloroform: methanol method described by Folch et al. (1957). Percent fat was calculated using the formula: Percent Fat = [(Total volume of chloroform: methanol)/10 x final lipid weight)/sample weight] x 100.

Ash Analysis

Ash was determined using the ashing method described in the AOAC 923.03 and 920.153 (1995). Briefly, approximately 1.0 g of sample was placed into a dry, pre-weighed crucible. Samples were then placed into a Thermolyne box furnace at 600°C for 18 h. Percent ash was calculated using the formula: Percent Ash = (ash weight / wet weight) x 100.

Statistical Design and Analysis

Experimental design

The study was designed to reflect the current fed beef carcass consist, with respect to Quality Grade (20% Upper Choice, 40% Lower Choice, 40% Select), Yield Grade (50% YG=2, 50% YG=3), sex classification (66.7% steers, 33.3% heifers) and cattle type (88.9% non-dairy, 11.1% dairy). To fabricate the cuts required for this phase, two carcasses labeled A or B with the same design factors and approximately the same marbling score were selected for inclusion in this study, resulting in 36 pairs of carcasses. The design was an incomplete block design with each university processing an incomplete replicate of the factor combinations. The replicates were incomplete because there were 16 combinations of design factors used in the study, and each university was assigned 10 unique combinations plus some replicate carcasses. Included were carcasses of 12 non-dairy heifers, 4 dairy steers and 20 non-dairy steers, resulting in 36 carcass pairs. The 36 carcass pairs were randomly assigned to plants for selection, with the restriction that the number of carcasses in each quality grade and in each yield grades be as equal as possible and that there be approximately twice as many carcasses of steers as heifers. Carcasses of dairy steers were available at only two plants, and carcasses of two dairy steers were selected at each of those plants. Because there were only carcasses of 4 dairy steers included, balancing the number of carcasses of dairy and non-dairy across quality grades was not possible. Three of the 24 Choice carcasses were from dairy cattle, while 1 of the 12 Select carcasses was generated from a dairy steer. Over all grades, 11.1% of carcasses were derived from dairy cattle, but the percentage of carcasses from dairy cattle in Select was 8.3%, and for Choice was 12.5%. Twelve carcass pairs were selected for each of the three quality grades.

Statistical analysis

A weighted least squares mean for each of the 36 carcasses was computed during analysis of variance for each cut and status of preparation (raw/cooked). Depending on the variable, these means were averaging across, multiple steaks/roast and/or multiple analytical values. The cattle type and sex classification factors were combined into a single factor, with three possible levels (non-dairy, steer; non-dairy, heifer; and dairy, steer). The mixed model analysis of variance included Quality Grade, CattleType-Sex, QG*CattleType-Sex and Yield Grade which were treated as fixed effects. Differences among universities and the residual variation were treated as random effects. Weighted least squares means were computed so that target design percentages for Quality Grade, Yield Grade, sex classification, and cattle type were achieved for all mean estimates.

RESULTS AND DISCUSSION

Separable Components

Means showing the effects of USDA Quality Grade on dissected separable components from raw and cooked retail cuts is presented in Table 3.1. Overall, USDA Quality Grade had minimal impact on the separable components from raw and cooked retail cuts. Raw USDA Select tenderloin roasts contained greater ($P < 0.05$) dissectible refuse than USDA Choice tenderloin roasts. Raw USDA Select top loin steaks with 0 cm trim had less ($P < 0.05$) separable external fat than did USDA Choice top loin steaks, resulting in steaks with increased ($P < 0.05$) separable lean amounts. Since cuts were trimmed to the same external fat level, Quality Grade should have had minimal effect on separable external fat amounts. This decrease in separable lean and increase in dissectible external fat with increased Quality Grade was not observed ($P > 0.05$) in the cooked top loin steaks. In cooked cuts, USDA Choice porterhouse steaks had greater

dissectible seam fat than Select porterhouse steaks. In addition, dissectible refuse amount was greater in Select porterhouse steaks and T-bone steaks than in Choice steaks. However, this trend was reversed for top loin steaks with 0 cm trim; Choice cuts had a greater percent of separable refuse than Select cuts.

Similarly, Martin et al. (2013) reported minimal impact of Quality Grade on separable components for retail cuts from the beef rib. Smith et al. (2011) reported that USDA Quality Grade had little effect on the separable lean of top loin steaks. However, Smith et al. (2011) determined that USDA Quality Grade did have an effect on separable fat and refuse in cooked top loin steaks. Smith et al. (2011) reported that USDA Select cooked top loin steaks contained a lower percent of separable fat and increased percent separable refuse as compared to Choice top loin steaks. For top loin steaks, tenderloin steaks, eye of round steaks, and top round steaks, Wahrmund-Wyle et al. (2000a) reported similar effects of USDA Quality Grade on separable components. Jones, Savell, and Cross (1990) determined that primals from Choice carcasses had increased intermuscular fat content than primals from Select carcasses. However in the current study, only the cooked porterhouse steak has more dissectible seam fat as a result of Quality Grade.

For most retail cuts, USDA Yield Grade and sex classification did not influence ($P > 0.05$) separable components (Tables 3.2 and 3.3, respectively). Percentage of dissectible lean was influenced ($P < 0.05$) by USDA Yield Grade for raw top loin steaks with 0.32 cm trim. Raw top loin steaks (0.32 cm trim) from Yield Grade 2 carcasses had greater ($P < 0.05$) percentages of separable lean than cuts from Yield Grade 3 carcasses (Table 3.2). This increase in percent separable lean was likely due to lower percent separable fat in the leaner Yield Grade 2 carcasses. Raw tenderloin roasts from steer carcasses had increased ($P < 0.05$) percentages of

dissectible refuse, while cooked T-bone steaks had lower ($P < 0.05$) proportions of separable external fat than the same steaks and roasts from heifer carcasses.

Overall, these results differed from previous studies in which increased USDA Yield Grades resulted in increased separable fat and decreased separable lean in beef carcasses and beef rib cuts (Ramsey et al., 1962; Wulf, Romans, and Costello et al., 1994; Martin et al., 2013). In addition, a previous cutability study reported heifer carcasses had more separable fat than steer carcasses (Murphey et al., 1985) and, in this present study, this difference due to sex classification was only true for one cut (Table 3.3). Compared to previous studies, the standardized trim levels of the present study were set at or below 0.32 cm for each cut regardless of Quality Grade, Yield Grade, or sex classification and this may have reduced the effect of Quality Grade, Yield Grade, and sex classification on separable components. Over the past two decades, the beef industry has striven to meet consumer demand for a leanness and little separable fat. Innovative fabrication techniques, in combination with increased trimming of beef cuts before retail display, has greatly reduced the amount of trimmable fat on all retail cuts. This present study indicated that, when external fat levels are standardized to levels at 0.32 cm or below, separable components generally will not be influenced by USDA Quality Grade, USDA Yield Grade, or sex classification.

Cooking Yield

Means corresponding to the main effects of USDA Quality Grade, USDA Yield Grade, and sex classification on cooking yields of individual cuts are presented in Table 3.4. Cooking for any individual cut was not impacted ($P > 0.05$) by USDA Quality Grade, USDA Yield Grade, or sex classification. Similarly, previous researchers reported that cooking yield was minimally affected by USDA Quality Grade or Yield Grade (Jones, Savell, and Cross, 1992;

Luchak et al., 1998; Smith et al., 2011; Wahrmund-Wyle et al., 2000a). However, external fat trim and cooking method can impact cooking yields (Jones, Savell, and Cross, 1992; Luchak et al., 1998; Wahrmund-Wyle et al., 2000a). Retail cuts with greater proportions of external fat generally have higher cooking yields than retail cuts with less or no external fat. However, since external fat trim level was standardized within each cut, it was unlikely that cook yields would be impacted. Previous studies noted that as cook time increases, cook yield decreased (Luchak et al., 1998). In the present study, cooking yield was affected ($P < 0.05$) by individual cut (Table A.3). Cooking yield of retail cuts decreased ($P < 0.05$) in the following order: porterhouse steaks (87.1%) = T-bone steaks (87.6%) > top loin steaks with external fat trimmed to 0.32 cm (85.7%) > top loin steaks with external fat trimmed to 0 cm trim (84.8%) > tenderloin roasts (82.0%) > tenderloin steaks (78.4%). As expected cuts with 0.32 cm trim had a greater ($P < 0.05$) cooking yield than cuts with 0 cm trim. Due to the design of the study, the effects of cooking method, external fat level, and cut could not be completely partitioned.

Proximate Composition

Protein

Quality Grade influenced ($P < 0.05$) protein content in raw loin cuts and cooked porterhouse, T-bone, and top loin steaks (Table 3.5). Generally, as Quality Grade (intramuscular fat) increased, protein content decreased ($P < 0.05$). The decreased protein content due to increased fat content was most evident when comparing Upper Choice, Low Choice, and Select cuts. For raw cuts, protein content for Choice and Select cuts only differed ($P > 0.05$) for the tenderloin steaks and roasts. Differences may not have been detected in protein content of round cuts and cooked tenderloin roasts due to the lower overall fat content of these cuts. Similarly, Brackebush et al. (1991) found that protein content tended to decrease with increased marbling

content. Other researchers determined that protein content of beef cuts decreased as Quality Grade (intramuscular fat) increased (Garrett and Hinman, 1971; Wahrmund-Wyle et al., 2000b; Smith et al., 2011). Data from the current study indicated that protein content is greater in cooked cuts than in raw cuts. Previous studies determined that during the cooking process, nutrients become more concentrated due to moisture loss, leading to greater protein content in cooked cuts compared to raw cuts (Wahrmund-Wyle et al., 2000b; Smith et al., 2011).

Similar to Martin et al. (2013), Yield Grade did not impact ($P > 0.05$) protein content of individual retail cuts (Table 3.5). Sex classification had no effect ($P > 0.05$) on protein content of retail cuts (Table 3.5). Garrett and Hinman (1971) found no protein differences as a result of Yield Grade; however, they determined steer carcasses had higher protein content than heifer carcasses. Previous data regarding the effects of Yield Grade and sex classification on the nutrient content of beef cuts is lacking since most previous studies were not designed to test such hypotheses.

Fat

For all raw and cooked retail cuts, total fat content increased ($P < 0.05$) with increasing USDA Quality Grade (Table 3.6). Choice retail cuts had greater ($P < 0.05$) fat content than Select retail cuts. Similarly, Garrett and Hinman (1971), Luchak et al. (1998), and Smith et al. (2011) reported fat content increased as marbling degree or USDA Quality Grade increased. Brackebusch et al. (1991) determined in fifteen muscles that marbling score was linearly related to percent fat. Since USDA Quality Grade increases with increasing marbling scores, the increased fat content was expected in cuts that contained more intramuscular fat. Parrett et al. (1989), Patten et al. (2008), Smith et al. (2011), and Wahrmund-Wyle et al. (2000b), Martin et al.

(2013) all found an increase in fat content of raw and/or cooked cuts as USDA Quality Grade increased.

Compared to previous beef nutrient composition studies, total fat content has decreased in cooked and raw top loin steaks and cooked tenderloin steaks. The decrease in total fat was likely due to different external fat levels. Previous studies evaluated the composition of cuts with 0 to 0.6 cm of external fat on steaks and roasts, while the present study evaluated cuts with a maximum of 0.32 cm external fat.

USDA Yield Grade and sex classification had no impact ($P > 0.05$) on total fat content of individual retail cuts (Table 3.6). Similarly, Rhee et al. (1982) reported that percent lipid did not differ in raw ribeye steaks for Yield Grade 2 and Yield Grade 3. Garrett and Hinman (1971) noted that, in beef carcasses, the total fat content of the carcasses increased with increasing USDA Yield Grade; but within Yield Grade 2 and Yield Grade 3, carcasses had similar crude fat content. Conversely, the researchers reported that fat content was greater in retail cuts from heifer carcasses compared with retail cuts from steer carcasses (Garrett and Hinman, 1971). Fat trim level impacts total fat content in retail cuts (Smith et al., 1989; Gerber et al., 2009). In the present study, fat trim level was specified for each individual cut, which may have reduced the impact of USDA Yield Grade and sex classification on total fat content. In a similar study of beef rib and plate retail cuts, Martin et al. (2013) reported that USDA Yield Grade had a minimal effect on fat content.

For raw loin cuts averaged across all USDA Quality Grades, USDA Yield Grades, and sex classifications, porterhouse steaks and T-bone steaks had the greatest ($P < 0.05$) fat content and top loin steaks and tenderloin steaks and roasts had the least ($P < 0.05$) fat content (Table A.4). A similar trend was observed for cooked lean cuts, except tenderloin roasts had the least (*P*

< 0.05) fat content. Differences in fat content between cuts were likely due to differences in external fat, seam fat, and/or cooking method.

Moisture

For all retail cuts, moisture content increased ($P < 0.05$) as USDA Quality Grade decreased (Table 3.7). Consistently, Select retail cuts had greater ($P < 0.05$) moisture content than Choice retail cuts. Previous studies reported that when cuts are stratified by USDA Quality Grade, as fat content increased, moisture content subsequently decreased (Miller et al., 1981 and 1987; Leheska et al., 2008; Duckett et al., 2009). Research has shown that an inverse relationship exists between the fat content and amount of water present within the muscle (Duckett et al., 1993; Patten et al., 2008; Smith et al., 2011.) Since fat content increases with increasing Quality Grade, the decreased moisture content was expected in cuts that contained more intramuscular fat.

USDA Yield Grade and sex classification did not affect ($P > 0.05$) moisture content on an individual cut basis (Table 3.7). Rhee et al. (1982) and Martin et al. (2013) also reported that sex classification and/or USDA Yield Grade did not have an impact on the moisture content of retail cuts. Standardized fat trim within individual cuts may have eliminated the effect of Yield Grade and sex classification on fat and moisture content. Comparing cooked loin cuts averaged across USDA Quality Grade, Yield Grade, and sex classification, tenderloin roasts had the greatest ($P < 0.05$) moisture content; it was the leanest cut likely due to a combination of cook method and external fat level (Table A.4).

Ash

The impact of Quality Grade, Yield Grade, and sex classification on the ash content of retail cuts was lessened as compared to other nutrients (Table 3.8). As Quality Grade increased

for cooked porterhouse steaks and top loin steaks (0.32 cm trim), ash content increased ($P < 0.05$). Total ash content for retail cuts did not differ ($P < 0.05$) due to the effect of USDA Yield Grade or sex classification. These results were similar to those reported previous studies in which ash content remained constant regardless of Quality Grade, Yield Grade, or sex classification (Wahrmund-Wyle et al., 2000b; Smith et al., 2011; Martin et al., 2013).

Conclusions

Results from this study provide relevant nutrient information based on current practices in the beef industry. These findings will be used to update the USDA Nutrient Database for Standard Reference which is used both domestically and internationally to provide consumers with information on the nutrient composition of retail beef cuts. Domestically, this information will be rapidly adapted for use on retail beef nutrition labels. In addition these data will be utilized to provide support for the consumption of lean beef as a part of a healthy diet.

Table 3.1. Effect of USDA quality grade on the least squares means of separable components (%) derived from ten raw and six cooked U.S. retail beef cuts

	Separable lean (%)[1]			Seam fat (%)[2]			External fat (%)[3]			Refuse (%)[4]		
Retail cut, trim level	Choice	Select	SEM	Choice	Select	SEM	Choice	Select	SEM	Choice	Select	SEM
Number of carcasses	24	12	-	24	12	-	24	12	-	24	12	-
Raw loin cuts												
Porterhouse steak, 0.32 cm	63.6	62.8	1.82	4.8	5.0	0.56	7.6	7.8	0.93	23.3	23.8	0.85
T-bone steak, 0.32 cm	59.9	59.3	1.76	5.6	5.2	0.80	8.8	9.8	0.73	25.1	25.9	0.77
Tenderloin roast, 0 cm	96.2	96.1	1.01	0.8	0.8	0.39	1.9	1.5	0.62	0.7^{b}	1.3^{a}	0.17
Tenderloin steak, 0 cm	97.5	97.6	0.76	0.3	0.4	0.43	1.8	1.6	0.56	0.10	0.06	0.091
Top loin steak, 0 cm	85.4^{b}	87.5^{a}	0.97	1.9	1.3	0.27	3.8^{a}	2.6^{b}	0.62	8.2	8.0	0.52
Top loin steak, 0.32 cm	77.7	78.5	1.45	2.6	2.2	0.39	11.8	11.5	1.40	7.2	6.9	0.81
Raw round cuts												
Eye of round roast, 0 cm	98.1	98.1	0.91	-	-	-	0.8	1.0	0.43	0.8	0.8	0.52
Eye of round steak, 0 cm	98.0	97.9	0.61	0.06	0.11	0.058	0.9	0.9	0.31	0.5	0.5	0.36
Top round roast, 0 cm	98.1	97.9	0.56	0.08	0.12	0.069	1.1	1.1	0.53	0.5	0.6	0.57
Top round steak, 0 cm	98.5	98.4	0.38	0.02	0.06	0.038	0.8	0.8	0.29	0.3	0.3	0.13
Cooked[5] loin cuts												
Porterhouse steak, 0.32 cm	61.7	59.3	1.69	4.6^{a}	3.6^{b}	0.61	7.3	6.5	0.67	25.9^{b}	29.9^{a}	1.60
T-bone steak, 0.32 cm	57.4	55.2	1.29	4.7	3.5	0.71	8.9	8.6	0.62	28.4^{b}	32.2^{a}	1.05
Tenderloin roast, 0 cm	98.3	98.4	0.48	0.7	0.6	0.44	0.6	0.4	0.12	0.2	0.3	0.13
Tenderloin steak, 0 cm	98.5	98.8	0.45	0.3	0.2	0.30	0.9	0.5	0.29	0.03	0.05	0.036
Top loin steak, 0 cm	87.1	87.2	1.88	1.4	1.1	0.31	3.6	2.6	0.71	8.6^{a}	7.4^{b}	1.18
Top loin steak, 0.32 cm	77.4	78.6	2.01	1.4	1.0	0.37	12.9	11.2	1.18	7.7	8.7	0.71

[1] Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2] Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3] External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4] Refuse weight (g) includes all bone and heavy connective tissue, include the membrane covering external fat. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-b] Within a row and separable component, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.2. Effect of USDA yield grade on the least squares means of separable components (%) derived from ten raw and six cooked U.S. retail beef cuts

	Separable lean (%)[1]			Seam fat (%)[2]			External fat (%)[3]			Refuse (%)[4]		
Retail cut, trim level	YG 2	YG 3	SEM	YG 2	YG 3	SEM	YG 2	YG 3	SEM	YG 2	YG 3	SEM
Number of carcasses	18	18	-	18	18	-	18	18	-	18	18	-
Raw loin cuts												
Porterhouse steak, 0.32 cm	63.7	62.9	1.73	4.6	5.1	0.50	7.5	79	0.89	23.5	23.5	0.71
T-bone steak, 0.32 cm	59.9	59.4	1.63	4.8	6.1	0.73	8.8	8.9	0.63	25.9	24.9	0.64
Tenderloin roast, 0 cm	95.9	96.4	0.98	0.8	0.9	0.38	2.1	1.4	0.59	0.9	1.0	0.14
Tenderloin steak, 0 cm	97.2	97.9	0.73	0.5	0.2	0.42	1.7	1.6	0.53	0.14	0.02	0.085
Top loin steak, 0 cm	86.0	86.4	0.92	1.6	1.7	0.23	3.2	3.4	0.58	8.4	7.7	0.44
Top loin steak, 0.32 cm	78.9[a]	77.1[b]	1.40	2.3	2.6	0.35	11.2	12.2	1.34	6.9	7.2	0.76
Raw round cuts												
Eye of round roast, 0 cm	98.4	97.8	0.90	-	-	-	0.7	1.0	0.40	0.5	0.9	0.51
Eye of round steak, 0 cm	98.1	97.8	0.59	0.07	0.08	0.049	0.7	1.0	0.30	0.6	0.5	0.35
Top round roast, 0 cm	97.9	98.1	0.54	0.08	0.12	0.068	1.1	1.1	0.52	0.6	0.4	0.31
Top round steak, 0 cm	98.3	98.6	0.37	0.04	0.03	0.036	1.0	0.6	0.28	0.3	0.3	0.12
Cooked[5] *loin cuts*												
Porterhouse steak, 0.32 cm	61.8	59.7	1.61	4.1	4.2	0.58	6.8	7.1	0.64	26.6	28.4	1.50
T-bone steak, 0.32 cm	57.9	56.1	1.17	4.0	4.3	0.65	8.6	9.1	0.52	29.9	29.9	0.90
Tenderloin roast, 0 cm	98.3	98.4	0.48	0.7	0.6	0.43	0.5	0.5	0.10	0.2	0.3	0.9
Tenderloin steak, 0 cm	98.7	98.5	0.41	0.3	0.2	0.3	0.6	0.8	0.26	0.04	0.04	0.031
Top loin steak, 0 cm	87.5	86.9	1.84	1.2	1.4	0.29	2.9	3.4	0.63	7.9	7.9	1.16
Top loin steak, 0.32 cm	78.1	77.6	1.99	1.4	1.1	0.35	11.7	12.7	1.12	8.2	8.0	0.66

[1] Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2] Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3] External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4] Refuse weight (g) includes all bone and heavy connective tissue, include the membrane covering external fat. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-b] Within a row and separable component, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.3. Effect of gender on the least squares means of separable components (%) derived from ten raw and six cooked U.S. retail beef cuts

	Separable lean (%)[1]			Seam fat (%)[2]			External fat (%)[3]			Refuse (%)[4]		
Retail cut, trim level	Heifer	Steer	SEM	Heifer	Steer	SEM	Heifer	Steer	SEM	Heifer	Steer	SEM
Number of carcasses	12	20	-	12	20	-	12	20	-	12	20	-
Raw loin cuts												
Porterhouse steak, 0.32 cm	63.4	63.5	1.84	5.5	4.8	0.57	7.7	7.8	0.94	22.7	23.4	0.87
T-bone steak, 0.32 cm	59.2	60.0	1.80	6.1	5.0	0.82	9.9	8.6	0.86	25.3	24.8	0.79
Tenderloin roast, 0 cm	96.7	95.9	1.02	0.8	0.7	0.39	1.6	1.9	0.63	0.4[b]	1.2[a]	0.17
Tenderloin steak, 0 cm	97.9	97.3	0.77	0.4	0.4	0.44	1.2	1.2	0.57	0.08	0.09	0.093
Top loin steak, 0 cm	85.8	86.5	0.99	1.8	1.5	0.28	4.1	3.1	0.63	7.7	8.4	0.54
Top loin steak, 0.32 cm	78.5	77.8	1.46	2.4	2.4	0.40	11.9	11.6	1.42	6.2	7.5	0.82
Raw round cuts												
Eye of round roast, 0 cm	98.3	97.9	0.92	-	-	-	0.6	1.1	0.44	0.8	0.8	0.53
Eye of round steak, 0 cm	97.9	98.0	0.61	0.17	0.04	0.059	0.8	0.9	0.32	0.5	0.5	0.36
Top round roast, 0 cm	98.0	98.0	0.57	0.12	0.09	0.064	1.1	1.1	0.53	0.4	0.6	0.12
Top round steak, 0 cm	98.4	98.5	0.39	0.06	0.03	0.039	0.8	0.8	0.29	0.4	0.3	0.13
Cooked[5] loin cuts												
Porterhouse steak, 0.32 cm	60.4	61.0	1.71	4.2	4.2	0.61	7.3	7.0	0.68	27.5	27.2	1.62
T-bone steak, 0.32 cm	55.8	56.5	1.32	4.0	4.5	0.73	10.2[a]	8.5[b]	0.64	29.5	29.9	1.08
Tenderloin roast, 0 cm	96.7	95.9	1.02	0.7	0.6	0.45	0.5	0.6	0.12	0.2	0.2	0.13
Tenderloin steak, 0 cm	98.8	98.5	0.46	0.3	0.3	0.31	0.5	0.8	0.25	0.04	0.06	0.031
Top loin steak, 0 cm	86.6	87.6	1.90	1.5	1.2	0.32	4.0	2.8	0.73	7.5	8.0	1.18
Top loin steak, 0.32 cm	77.5	78.0	2.02	1.5	1.1	0.38	13.1	11.8	1.19	7.4	8.5	0.72

[1] Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.
[2] Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.
[3] External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.
[4] Refuse weight (g) includes all bone and heavy connective tissue, include the membrane covering external fat. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-c] Within a row and separable component, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.4. Effects of USDA quality grade, USDA yield grade, and gender on the least squares means of cooking[1] yield[2] (%) for six cooked U.S. retail beef cuts

	USDA Quality Grade						USDA Yield Grade			Gender		
Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	YG 2	YG 3	SEM	Heifer	Steer	SEM
Number of carcasses	12	12	24	12	-	36	18	18	-	12	20	-
Porterhouse steak, 0.32 cm	87	87	87	87	1.8	87	87	87	1.7	87	87	1.8
T-bone steak, 0.32 cm	88	88	88	87	1.5	88	88	88	1.5	88	88	1.5
Tenderloin roast, 0 cm	83	81	82	82	0.9	82	83	81	0.8	83	81	0.9
Tenderloin steak, 0 cm	79	79	79	78	2.0	78	78	78	2.0	79	78	2.0
Top loin steak, 0 cm	85	84	85	85	1.0	85	85	85	1.0	84	85	1.1
Top loin steak, 0.32 cm	86	86	86	85	1.1	86	86	85	1.1	85	86	1.1

[1] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

[2] Cooking yield, %: (hot cooked weight/pre-cooking raw weight) x 100.

Table 3.5. Effects of USDA quality grade, USDA yield grade, and gender on the protein content (g/100g) of the separable lean from ten raw and six cooked U.S. retail beef cuts

	USDA Quality Grade						USDA Yield Grade			Gender		
Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	YG 2	YG 3	SEM	Heifer	Steer	SEM
Number of carcasses	12	12	24	12	-	36	18	18	-	12	20	-
Raw												
Porterhouse steak, 0.32 cm	21.7^{b}	22.3^{a}	22.1^{z}	22.6^{az}	0.38	22.3	22.4	22.3	0.35	22.5	22.3	0.37
T-bone steak, 0.32 cm	21.7^{b}	22.3^{a}	22.1^{z}	22.4^{az}	0.38	22.2	22.2	22.2	0.39	22.3	22.2	0.40
Tenderloin roast/steak, 0 cm[1]	21.7^{b}	21.8^{ab}	21.8^{y}	22.2^{az}	0.38	21.9	21.9	22.0	0.35	22.0	22.0	0.36
Top loin steak, 0 and 0.32 cm[2]	22.7^{b}	23.0^{ab}	22.9^{z}	23.3^{az}	0.38	23.1	23.2	23.0	0.37	23.0	23.2	0.39
Eye of round roast/steak, 0 cm[3]	23.4^{a}	23.3^{a}	23.4^{z}	23.4^{az}	0.31	23.4	23.4	23.3	0.29	23.5	23.3	0.30
Top round roast/steak, 0 cm[4]	23.5^{a}	23.7^{a}	23.6^{z}	23.6^{az}	0.32	23.6	23.6	23.6	0.37	23.7	23.5	0.38
Cooked[5]												
Porterhouse steak, 0.32 cm	27.0^{b}	28.1^{a}	27.7^{y}	29.1^{az}	0.66	28.0	28.0	28.0	1.00	28.0	28.0	1.10
T-bone steak, 0.32 cm	26.9^{b}	27.7^{ab}	27.5^{y}	28.4^{az}	0.63	27.9	28.1	27.6	0.70	28.0	27.8	0.73
Tenderloin roast, 0 cm	27.2^{a}	27.6^{a}	27.5^{z}	27.5^{az}	0.64	27.5	27.2	27.8	0.46	27.5	27.7	0.49
Tenderloin steak, 0 cm	30.1^{a}	30.6^{a}	30.4^{z}	31.2^{az}	0.74	30.7	30.6	30.8	1.2	30.3	31.0	1.20
Top loin steak, 0 cm	28.3^{b}	29.6^{b}	29.2^{z}	29.9^{az}	0.67	29.3	29.6	29.4	0.30	29.7	29.6	0.30
Top loin steak, 0.32 cm	28.3^{b}	28.8^{ab}	28.7^{y}	29.6^{az}	0.71	29.1	29.2	28.9	0.34	29.1	29.3	0.40

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.
[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).
[yz] Within a row and USDA Quality Grade, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.6. Effects of USDA quality grade, USDA yield grade, and gender on the fat content (g/100g) of separable lean from ten raw and six cooked U.S. retail beef cuts

	USDA Quality Grade						USDA Yield Grade			Gender		
Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	YG 2	YG 3	SEM	Heifer	Steer	SEM
Number of carcasses	12	12	24	12	-	36	18	18	-	12	20	-
Raw												
Porterhouse steak, 0.32 cm	8.5^{a}	6.8^{b}	7.4^{z}	5.4^{cy}	0.63	6.6	6.4	6.8	0.74	6.8	6.4	0.77
T-bone steak, 0.32 cm	8.8^{a}	6.6^{b}	7.3^{z}	5.3^{cy}	0.63	6.5	6.4	6.6	0.47	6.5	6.5	0.52
Tenderloin roast/steak, 0 cm[1]	6.5^{a}	6.0^{b}	6.2^{z}	5.1^{cy}	0.63	5.7	5.6	5.9	0.41	5.6	5.6	0.45
Top loin steak, 0 and 0.32 cm[2]	6.8^{a}	6.1^{b}	6.3^{z}	4.7^{cy}	0.63	5.7	5.6	5.8	0.59	5.8	5.3	0.64
Eye of round roast/steak, 0 cm[3]	3.6^{a}	3.3^{a}	3.4^{z}	2.5^{by}	0.41	3.0	3.1	3.0	0.49	3.0	2.8	0.34
Top round roast/steak, 0 cm[4]	3.7^{a}	3.0^{ab}	3.3^{z}	2.5^{by}	0.41	2.9	2.9	3.0	0.49	3.0	2.8	0.50
Cooked[5]												
Porterhouse steak, 0.32 cm	12.6^{a}	10.7^{a}	11.4^{z}	8.8^{by}	0.87	10.3	9.5	11.1	0.82	10.8	10.1	0.87
T-bone steak, 0.32 cm	12.5^{a}	10.4^{b}	11.0^{z}	9.3^{by}	0.87	10.4	10.0	11.0	1.10	11.0	10.0	1.10
Tenderloin roast, 0 cm	8.9^{a}	7.7^{ab}	8.1^{z}	6.6^{by}	0.87	7.5	7.3	7.7	0.76	7.5	7.3	0.83
Tenderloin steak, 0 cm	10.2^{a}	8.4^{ab}	9.0^{z}	7.2^{by}	0.87	9.1	8.2	8.5	1.00	8.4	7.9	1.10
Top loin steak, 0 cm	10.8^{a}	9.0^{a}	9.5^{z}	6.9^{by}	0.87	8.4	8.7	8.1	0.40	8.7	7.9	0.50
Top loin steak, 0.32 cm	11.6^{a}	9.8^{ab}	10.3^{z}	7.4^{by}	0.87	9.1	8.8	9.4	0.38	9.4	8.4	0.47

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.
[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).
[yz] Within a row and USDA Quality Grade, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.7. The effects of USDA quality grade, USDA yield grade, and gender on the moisture content (g/100g) of the separable lean from ten raw and six cooked U.S. retail beef cuts

	USDA Quality Grade						USDA Yield Grade			Gender		
Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	YG 2	YG 3	SEM	Heifer	Steer	SEM
Number of carcasses	12	12	24	12	-	36	18	18	-	12	20	-
Raw												
Porterhouse steak, 0.32 cm	68.5^{c}	70.1^{b}	69.6^{y}	71.4^{az}	0.52	70.3	70.5	70.1	0.48	70.0	70.5	0.52
T-bone steak, 0.32 cm	68.8^{c}	70.5^{b}	70.0^{y}	71.9^{az}	0.52	70.7	70.8	70.6	0.28	70.7	70.6	0.33
Tenderloin roast/steak, 0 cm[1]	71.6^{b}	72.3^{ab}	72.0^{y}	73.1^{az}	0.52	72.4	72.7	72.2	0.34	72.3	72.5	0.38
Top loin steak, 0 and 0.32 cm[2]	69.8^{b}	70.0^{b}	69.9^{y}	71.6^{az}	0.52	70.6	70.7	70.5	0.69	70.6	70.8	0.72
Eye of round roast/steak, 0 cm[3]	73.0^{b}	73.3^{b}	73.2^{y}	73.8^{az}	0.51	73.4	73.5	73.4	0.47	73.2	73.5	0.48
Top round roast/steak, 0 cm[4]	72.6^{b}	72.7^{ab}	72.7^{y}	73.4^{az}	0.53	73.0	73.0	73.0	0.69	72.8	73.0	0.70
Cooked[5]												
Porterhouse steak, 0.32 cm	59.8^{b}	60.6^{b}	60.3^{y}	62.1^{az}	0.58	61.0	61.7	60.4	0.62	60.4	61.2	0.69
T-bone steak, 0.32 cm	59.5^{b}	61.1^{a}	60.6^{y}	62.0^{az}	0.58	61.2	61.6	60.8	0.56	60.9	61.2	0.61
Tenderloin roast, 0 cm	63.9^{b}	64.4^{ab}	64.2^{y}	65.8^{az}	0.58	64.8	65.2	64.4	0.41	64.7	64.8	0.50
Tenderloin steak, 0 cm	59.5^{b}	60.6^{ab}	60.2^{y}	61.5^{az}	0.58	60.8	61.1	60.5	0.84	60.9	60.9	0.90
Top loin steak, 0 cm	60.4^{b}	60.9^{b}	60.7^{y}	63.3^{az}	0.58	61.7	61.8	61.7	0.43	61.2	62.1	0.50
Top loin steak, 0.32 cm	60.0^{b}	60.8^{b}	60.6^{y}	63.0^{az}	0.87	61.5	61.8	61.3	0.67	61.1	61.8	0.74

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.
[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).
[yz] Within a row and USDA Quality Grade, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table 3.8. The effects of USDA quality grade, USDA yield grade, and gender on the ash content (g/100g) of the separable lean from ten raw and six cooked U.S. retail beef cuts

Retail cut, trim level	USDA Quality Grade						USDA Yield Grade			Gender		
	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	YG 2	YG 3	SEM	Heifer	Steer	SEM
Number of carcasses	12	12	24	12	-	36	18	18	-	12	20	-
Raw												
Porterhouse steak, 0.32 cm	1.01	1.01	1.01	1.03	0.043	1.02	1.02	1.02	0.034	1.01	1.03	0.035
T-bone steak, 0.32 cm	0.98	1.01	1.00	1.02	0.043	1.01	1.01	1.00	0.024	1.01	1.01	0.025
Tenderloin roast/steak, 0 cm[1]	1.11	1.11	1.11	1.10	0.043	1.11	1.11	1.10	0.056	1.11	1.09	0.057
Top loin steak, 0 and 0.32 cm[2]	1.02	1.00	1.01	1.04	0.043	1.02	1.01	1.04	0.053	1.02	1.03	0.054
Eye of round roast/steak, 0 cm[3]	1.11	1.10	1.10	1.09	0.045	1.10	1.09	1.11	0.041	1.10	1.10	0.042
Top round roast/steak, 0 cm[4]	1.13	1.12	1.12	1.12	0.045	1.12	1.11	1.13	0.041	1.13	1.11	0.042
Cooked[5]												
Porterhouse steak, 0.32 cm	1.05[ab]	1.01[b]	1.02	1.11[b]	0.039	1.05	1.05	1.06	0.031	1.09	1.03	0.036
T-bone steak, 0.32 cm	1.03	1.03	1.02	1.09	0.036	1.05	1.07	1.03	0.025	1.06	1.03	0.029
Tenderloin roast, 0 cm	1.25	1.24	1.25	1.23	0.041	1.25	1.22	1.27	0.070	1.23	1.22	0.071
Tenderloin steak, 0 cm	1.38	1.38	1.38	1.37	0.048	1.40	1.40	1.40	0.056	1.30	1.40	0.060
Top loin steak, 0 cm	1.11	1.15	1.14	1.17	0.039	1.1	1.2	1.1	0.025	1.10	1.20	0.024
Top loin steak, 0.32 cm	1.09[b]	1.16[a]	1.13	1.17[b]	0.039	1.15	1.14	1.15	0.029	1.14	1.14	0.033

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).

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CHAPTER IV

NUTRIENT DATABASE IMPROVEMENT PROJECT: FATTY ACID PROFILE AND CHOLESTEROL CONTENT OF RAW AND COOKED RETAIL CUTS FROM THE BEEF LOIN AND ROUND

SUMMARY

The fatty acid profile and cholesterol content of beef cuts have been heavily scrutinized. The objective of this study was to analyze the fatty acid composition and cholesterol content of ten beef loin and round cuts to update the nutrient data in the USDA National Nutrient Database for Standard Reference. Beef short loins, strip loins, tenderloins, inside rounds, and eye of rounds (IMPS # 173, 175, 190A, 169A, and 171C) were collected from 72 carcasses to represent the national consist and shipped to three university meat laboratories for storage, retail fabrication, compositing, and raw/cooked analysis of nutrients. Composite samples were analyzed for fatty acid and cholesterol content. Results from this study indicate that beef has a favorable fatty acid profile with approximately 50 percent of the total fatty acids present in beef being monounsaturated or polyunsaturated fatty acids. This study identified four Upper Choice, seven Low Choice, and eight Select cuts that qualify for the lean nutrient claim based on cooked separable lean values.

INTRODUCTION

Since 1977, the USDA Dietary Guidelines for Americans have encouraged consumers to decrease their consumption of total fat, saturated fat, and cholesterol (USDA, 2010). The 2010 Dietary Guidelines for Americans recommended that individuals consume less than 10% of their energy from saturated fats and less than 300 mg of cholesterol per day (USDA, 2010). In order to achieve these recommendations, many Americans believe that it is necessary to eliminate beef

products from their diet due to the saturated fat and cholesterol content (Guenther, 2005). The belief that beef products cannot be a part of a healthy diet is one reason that per capita consumption of beef has declined from 38.4 kg in 1970 to 25.8 kg in 2010 (USDA, 2012).

However, previous research studies have suggested that beef products have a favorable fatty acid profile (Leheska et al., 2008; Duckett et al., 2009; Desimone et al., 2013). Over half of the fatty acids in beef are monounsaturated or polyunsaturated fatty acids (Leheska et al., 2008; Duckett et al., 2009; Desimone et al., 2013). Beef is the largest source of monounsaturated fatty acids in the American diet (Cotton et al., 2004). In addition, only one-third of the fatty acids found in beef are known to raise serum cholesterol levels. Stearic acid makes up approximately one-third of all saturated fatty acids found in beef and is known to have a neutral effect on serum cholesterol levels. A recent randomized control study reported that a diet containing 113 g of lean beef per day can reduce total and low density lipoprotein cholesterol levels to the same extent as the Dietary Approaches to Stop Hypertension diet which limits beef consumption to approximately 28 g per day (Roussell et. al, 2012).

With implementation of nutrition labeling of single-ingredient products and ground or chopped meat and poultry products, certain raw retail beef cuts will be required to be labeled with nutrient content information about the fat and cholesterol content of the product (FDA, 2010). The information for these labels will be generated from the published beef nutrient data in the USDA National Nutrient Database for Standard Reference (SR). The database is utilized worldwide for food composition comparisons (Merchant and Dehghan, 2006). Updating the SR is an ongoing process since animal management and carcass fabrication procedures are constantly improving and new methods of cooking are used. Conducting research to provide relevant beef nutrient data is important so that the values can be included on on-package labels

for fresh beef and to identify cuts that are classified as “lean” or “extra lean” and potentially use them in the newly redesigned school lunch programs or in other institutional dining situations. The objective of this study was to evaluate the effects of USDA Quality Grade on retail cut fatty acid profiles and cholesterol content. To accomplish this objective, carcasses were identified and 10 retails cuts from the loin and round were used for generation of fatty acid and cholesterol content values.

MATERIALS AND METHODS

Carcass selection, retail cut fabrication, cooking, dissection, and homogenization procedures were described previously in Chapter 3.

Carcass Selection and Subprimal Collection

Seventy-two beef carcasses from seven different packing plants in six different regions, (Greenbay, WI; Greeley, CO; Dodge City, KS; Tolleson, AZ; Plainview, TX; Omaha, NE; Corpus Christi, TX) of the Unites States were selected based on national representation of Quality Grade, Yield Grade, gender and genetic type. All carcasses selected had to be of A maturity for both lean and skeleton. Two carcasses (A and B) were selected for each sample number in the matrix to ensure adequate sample amounts to represent all retail cuts. The paired A and B carcasses were required to have similar marbling scores so that the scores did not cross the grade lines as well as possessing all other characteristics within the sampling criteria. Carcasses fitting the selection criteria were selected and identified accordingly.

After identification of carcasses fitting the sampling matrix, subprimals from the loin and round (IMPS No. 173, 175, 190A, 169A, and 171C) were fabricated according to plant protocol. Subprimals were then collected by university personnel and shipped via refrigerated truck to the

one of three universities where they were stored in the absence of light at 0 to 4^{o}C until retail cut fabrication.

Retail Cut Fabrication

Between 14 to 21 d postmortem, subprimals were fabricated into pre-identified retail cuts. Porterhouse steaks and T-Bone steaks were obtained from the short loin. Steaks from the short loin were classified according to width of the tenderloin, which was measured perpendicular to the transverse process. Porterhouse steaks were classified as having a minimum tenderloin width of 3.18 cm, while steaks with a tenderloin width from 1.27 to 3.18 cm were designated as T-Bones. External fat on the porterhouse and T-Bone steaks was trimmed to 0.32 cm. Top loin steaks were obtained from the strip loin. Steaks with *Gluteus medius* present on both sides of the steak were identified as vein steaks and were not used for nutrient analysis in this study. The external fat trim levels of 0 cm to 0.32 cm were assigned to alternating steaks. Steaks and roasts were obtained from the tenderloin, eye of round, and top round. All retail cuts originating from the tenderloin, eye of round, and top round were trimmed to an external fat thickness of 0 cm.

Cooking of Retail Cuts

Before cooking, retail cuts designated for cooking were tempered in a single layer at 0 to 4°C for 24 or 48 h. Retail cuts from the round were not cooked. Those cuts assigned to grilling were: porterhouse steaks, T-Bone steaks, tenderloin steaks, and top loin steaks (0 cm and 0.32 cm). A Salton two-sided electric grill (Model GRP99, Salton Inc., Lake Forest, IL) was utilized to cook each steak to an internal temperature of 70^{o}C which was monitored using digital thermocouple thermometers (Digi-Sense; Cole Parmer, Vernon Hills, IL) and probes (Type J, Cole Parmer, Vernon Hills, IL).

Tenderloin roasts were the only cut assigned to roasting. Each individual tenderloin roast was placed in a non-stick anodized aluminum roasting pan with rack (Calphalon Corp., Toledo, OH). Two roasting pans were placed in an oven that was pre-heated to 160°C and cooked until reaching an internal temperature of 60°C. Roasts were then removed from the oven and placed on a wire rack to record peak temperature. All cooked samples were allowed to chill uncovered on wire racks under refrigeration (0 to 4°C) for at least 12 h before cooked dissection.

Retail Cut Dissection

Raw and cooked retail cuts were dissected to yield the following components:

- Refuse (waste) – defined as all bone and heavy connective tissue.
- Separable lean – included all muscle, intramuscular fat and any light connective tissue considered edible.
- External fat – defined as the adipose tissue located on the outer surface of the cut and above the bridge of the muscles.
- Seam fat – included all fat deposited between muscles in a cut. After recording the lip fat weight, the lip fat was added to the seam fat for homogenization.

Raw and cooked top loin steaks with 0 and 0.32 cm external fat trim were also dissected to yield the following components.

- Lip lean – included all lean from the lip. The lip was defined as the portion past the ventral curvature of the *Longissimus dorsi*.
- Lip fat – included all fat from the lip region as previously defined.

Retail Cut Homogenization

Due to the sensitivity of B vitamins and other nutrients, and to prevent contamination, homogenization and aliquoting procedures were performed in the absence of direct light and

powder-free nitrile gloves were worn. Samples of the same cut from the same individual carcasses that were also subjected to the same cooking method were homogenized together. Following dissection, each retail cut was cut into 2.5-cm^3 pieces and the pieces were submerged in liquid nitrogen until all pieces were completely frozen. A 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS) was utilized to blend the sample until the sample appeared finely powdered and homogenized. Individual samples were then shipped to Texas Tech University (Lubbock, TX) for central compositing of individual cuts.

Retail Cut and Fat Compositing

To conduct national nutrient analysis, individual cuts from all universities were composited to form composites on a six, three, and national level (Figure 4.1). The six-level composite samples contained lean from six individual carcasses representing each quality grade (Upper Choice, Low Choice, and Select). The six-level composite samples were used to make the three-level composite samples. Twelve carcasses were represented in each three-level composite sample. The national composite represented the two USDA quality grades (Choice and Select). The amount of sample originating from each individual carcass was equal among all carcasses and was specific to the nutrient analysis to be performed for the respective cut.

Nutrient Analyses

Total lipid analysis

Total lipid analysis was performed on the six- level composite samples. Total lipid was extracted from 1-g subsamples of homogenized tissue using the method of Folch et al. (1957) as modified by Bligh and Dyer (1959). After extraction, the lipid-containing fraction was dried under N2 gas and placed in a 100*C drying oven for 3 h. The pre-weighed vial containing the

dried lipid extract was then allowed to cool in a desiccator and weighed to determine percent lipid.

Fatty Acid Analysis

Fatty acid analysis was performed by Texas A&M University and Colorado State University at the six-level composite. At Colorado State University, fatty acid methyl esters (FAMES) were prepared as described by Parks and Goins (1994) and analyzed via liquid chromatography using an Agilent (Avondale, PA) Model 6890 Series II gas chromatograph fixed with a Series 7683 injector and flame ionization detector. The instrument was equipped with a100-m x 0.25-mm (id) fused silica capillary column (SP-2560 Supelco Inc. Bellefonte, PA). Conjugated linoleic acid (CLA) analysis at Colorado State University was performed using the methods described by Phillips et al. (2010). At Texas A&M University fatty acid methyl esters, including CLA, were determined using a Varian gas chromatograph (model CP-3800 fixed with a CP-8200 autosample; Varian, Inc., Walnut Creek, CA) with methods described by Smith et al. (2002). Separation of FAMES was performed using a fused silica capillary column with helium as the carrier gas. Individual FAMEs were quantified as percentage of total FAME analyzed.

Cholesterol Analysis

At Colorado State University and Texas Tech University, total cholesterol content was determined as described by Dinh et al. (2008). Briefly, samples were accurately weighed and placed into a 125-mL boiling flask containing 2 mL of 50% potassium hydroxide in water and 10 mL of 95% ethanol, and then refluxed for 15 min and allowed to cool to room temperature. Toluene (10mL; Sigma-Aldrich) was added, mixed, and then transferred to a separatory funnel and washed. Toluene solution containing the extracted cholesterol was mixed with an internal standard (5alpha-cholestane; Sigma-Aldrich) and placed in a 2.0 mL gas chromatography vial

and subjected to gas chromatography analysis using the above described gas chromatography equipped with a DB-17 capillary column (30 m x 0.250 mm x 0.15 um; Agilent Tech. Inc.). The inlet temperature was 250^{o}C and split ratio was 10:1 as described by Dinh et al., (2008).

Cholesterol analyses at Texas A&M University were performed using the gas chromatography determination method described by Rule et al. (2002). Briefly, samples were subjected to direct saponification at 90^{o}C with 1.18 *M* KOH in ethanol. Cholesterol was then quantified by gas chromatography using an SPB-1, fused capillary column (30 mm 53mm i.d.; Suppelco, Bellefonte, PA) with column temperature at 250°C and detector and injector temperatures at 300°C as described by Rule et al. (1997).

Statistical design and analysis

The study was designed to reflect the national carcass consist for Quality Grade (20% Upper Choice, 40% Low Choice, 40% Select), Yield Grade (50% YG=2, 50% YG=3), sex classification (66.7% steers, 33.3% heifers) and cattle type (88.9% non-dairy, 11.1% dairy). To fabricate the cuts required for this phase two carcasses labeled A or B with the same design factors and approximately the same marbling score were selected resulting in 36 pairs of carcasses. The design was completely randomized. There were 12 non-dairy heifers, 4 dairy steers and 20 non-dairy steers resulting in 36 carcass pairs.

For six composite data, a mean for each composite was computed for analysis averaging across multiple analytical values. The model defined Quality Grade as fixed and the residual variation as random. Weighted least squares were computed so that design percentages for quality grades were achieved. Compositing proportions were used to achieve the desired mix of yield grades, sex classes, and approximate mix of cattle type.

RESULTS AND DISCUSSION

Fatty Acid Composition

Fatty acid composition of separable lean from raw and cooked retail cuts are presented in Tables 4.1 through 4.4. The fatty acid content expressed as g per 100 g separable lean tissue for the cooked and raw retail cuts is presented in Tables 4.1 and 4.2. Quality Grade impacted ($P < 0.05$) saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), and/or *trans* fatty acid content of raw and cooked loin cuts. Saturated fatty acid content and MUFA content were influenced by Quality Grade in a greater number of cuts than PUFA and *trans* fatty acid content. All differences among the loin cuts were a result of increased fat content due to increased Quality Grade. Round cuts were not influenced ($P > 0.05$) by Quality Grade for SFA, MUFA, PUFA, or *trans* fatty acid content.

Differences were present when the fatty acid content was expressed as g per 100 g of separable lean tissue; however, these same differences were not found when fatty acids were expressed as a percentage of total fatty acids (Tables 4.3 and 4.4) indicating that, regardless of Quality Grade, beef retail cuts from the loin and round have a similar fatty acid composition. However, the content of individual fatty acids may vary with overall fat levels of a cut.

Of the fatty acids identified, retail cuts contained between 40.8 to 46.1, 40.8 to 46.8, and 4.4 to 9.1 percent weight SFA, MUFA, and PUFA, respectively. These results were similar to those of Leheska et al. (2008) who reported LD concentrations of 45.1, 51.6, and 3.4 percent for SFA, MUFA, and PUFA, respectively. Differences in the fatty acid profile of cuts between studies were likely due to the different muscles of the various retail cuts, as well as to the variations in total fat concentration. Of the SFA identified, mysteric and palmitic acids have the greatest effect on serum cholesterol, while steric acid has no effect on blood cholesterol (Aherns

et al., 1957; Keys et al., 1965). Monounsaturated fatty acids and polyunsaturated fatty acids have been shown to have positive health benefits (Ruxton et al., 2004; Lopez-Miranda et al., 2006). Cotton et al. (2004) reported that beef is the number one source of MUFA in the American diet.

Results from this study support previous studies where approximately fifty percent of the fatty acids in beef fat were MUFA and PUFA (Leheska et al., 2008; Duckett et al., 2009; Desimone et al., 2013). Leheska et al. (2008) and Eichhorn et al. (1985) found that oleic, palmitic and stearic acids represent the majority of the fatty acid profile in bovine muscle. Similarly, in the present study, oleic, palmitic, and stearic acid represented over 77% of the total fatty acids identified in raw and cooked retail cuts from the loin and round. The largest fatty acid identified in these cuts was oleic acid, however, approximately palmitic acid made up approximately 25% of the fatty acids identified. Palmitic acid consumption should be decreased due to its effect on serum cholesterol (Aherns et al., 1957). Beef is the number one source of total fat and number two source of saturated fat in the American diet (Cotton et al., 2004). The percent of *trans* fatty acids present in raw and cooked retail cuts ranged from 4.5 to 6.8 percent of total fatty acids. The 2010 Dietary Guidelines for Americans (USDA, 2010) encouraged consumers to reduce the consumption of *trans* fatty acids in the diet. However compared to *trans* fatty acids found in partially hydrogenated vegetable oils, ruminant *trans* fatty acids have a neutral or potentially beneficial effect on LDL cholesterol, HDL cholesterol, and total triglycerides (Terpstra, 2004; Tricon et al., 2004). In addition, beef serves as a source of conjugated linoleic acid. Between 0.34 to 0.58 percent of the fatty acids present in retail cuts were isomers of conjugated linoleic acid. Studies on human and mouse models have shown that CLA may: prevent cholesterol-induced coronary heart disease; reduce whole body fat; enhance

immune response; inhibit carcinogenesis; improve diabetes; and improve bone metabolism (Tanka, 2005; Scollan et al., 2006)

Cholesterol Content

The influence of USDA Quality Grade on cholesterol content of raw and cooked retail beef cuts is presented in table 4.5. For all raw and cooked retail cuts, Quality Grade ($P > 0.05$) did not influence cholesterol content. In beef muscle tissue, cholesterol is primarily located in the membrane component of cells. Adipose tissue found within a beef retail cut contributes a small amount of the total cholesterol in a serving of beef (Hoelscher et al., 1988; Sweeten et al., 1990a; Sweeten et al., 1990b). In addition, intermuscular fat has been found to contain more cholesterol than intramuscular fat (Sweeten et al., 1990b). In the current study, all intermuscular fat was removed from each cut before nutrient analysis; thus, intramuscular fat served as the only fat source in each beef cut. Due to the small influence of intramuscular adipose tissue on cholesterol content, previous studies also noted that cholesterol content was not impacted due to the Quality Grade or fat levels of a retail cut (Rhee et al., 1988; Browning et al., 1990; Leheska et al., 2008).

Cholesterol content differed ($P < 0.05$) by cut for cooked loin cuts. Grilled tenderloin steaks contained greater ($P < 0.05$) content of cholesterol than the other cooked retail cuts from the loin. The difference in cholesterol content may have been due to the extremely low fat levels in the grilled tenderloin steaks. Since cholesterol is mainly found in the membrane component of cells, such as muscle cells, the presence of more muscle cells may have increased the total cholesterol content for grilled tenderloin steaks. In addition, cooking will impact the cholesterol content of a cut (Chizzolini et al., 1999). During the cooking process, water is removed so the cholesterol content of a cut will increase on a wet-matter basis. In the current study, grilled

tenderloin steaks had the greatest cook loss which may have impacted the total cholesterol content of the cooked cut.

Cholesterol content of raw beef cuts based on All Grades data in the current study ranged from 58 to 62 mg/100 g of lean tissue. This was similar to total cholesterol content ranges reported by previous studies (Reisser 1975; Slover et al., 1987; Rule et al., 2002; Leheska et al., 2008; Duckett et al., 2009). Cholesterol content of cooked beef cuts has not been explored to the same extent as the cholesterol content of raw cuts. In the current study, cholesterol content of cooked beef cuts ranged from 80 to 92 mg/100 g of lean tissue. Slover et al. (1987) and Swize et al. (1992) reported similar ranges in cholesterol for cooked top loin steaks and tenderloin steaks. In addition, Swize et al. (1992) reported that total cholesterol content decreased with increased fat content. Compared to nutrient data in the USDA Nutrient Database for Standard Reference 24, cooked beef cuts in the current study had decreased total lipid levels and increased total cholesterol content (USDA-ARS, 2011). These results were similar to those reported in previous studies where total fat content decreased specifically through decreased intermuscular fat that total cholesterol content increased for the individual cut (Swize et al., 1992; Chizzolini et al., 1999).

Lean cuts

The United States Department of Agriculture (2012) defines lean as less than 10.0 g total fat, 4.5 g or less saturated fat, and less than 95 mg of cholesterol per 100 g serving. Extra lean as less than 5.0 g total fat, 2.0 g or less saturated fat, as and less than 95 mg cholesterol per 100 g serving. Based on these definitions, the following cooked retail cuts can be classified as “lean” based on the separable lean nutrient data:

Porterhouse steaks from Select carcasses,

T-bone steaks from Low Choice and Select carcasses,

Top loin steaks with 0.32 cm external fat from Low Choice and Select carcasses,

Top loin steaks with 0 cm external fat from Low Choice and Select carcasses,

Tenderloin roasts from Upper Choice, Low Choice, and Select carcasses, and

Tenderloin steaks from Upper Choice, Low Choice and Select carcasses.

Conclusions

Results from this study provide relevant nutrient information concerning the fatty acid composition and cholesterol content of retail beef cuts from the loin and round based on current practices in the beef industry. Results from this study indicated that beef has a favorable fatty acid profile with approximately 50 percent of the total fatty acids present in beef being monounsaturated or polyunsaturated fatty acids. This study identified four Upper Choice, seven Low Choice, and eight Select cuts that qualify for the" lean" nutrient claim based on cooked separable lean values.

These findings will be used to update the USDA Nutrient Database for Standard Reference which is used both domestically and internationally to provide consumers with information on the nutrient composition of retail beef cut. Domestically, this information can be used to help make nutrient content claims on labels for beef products.

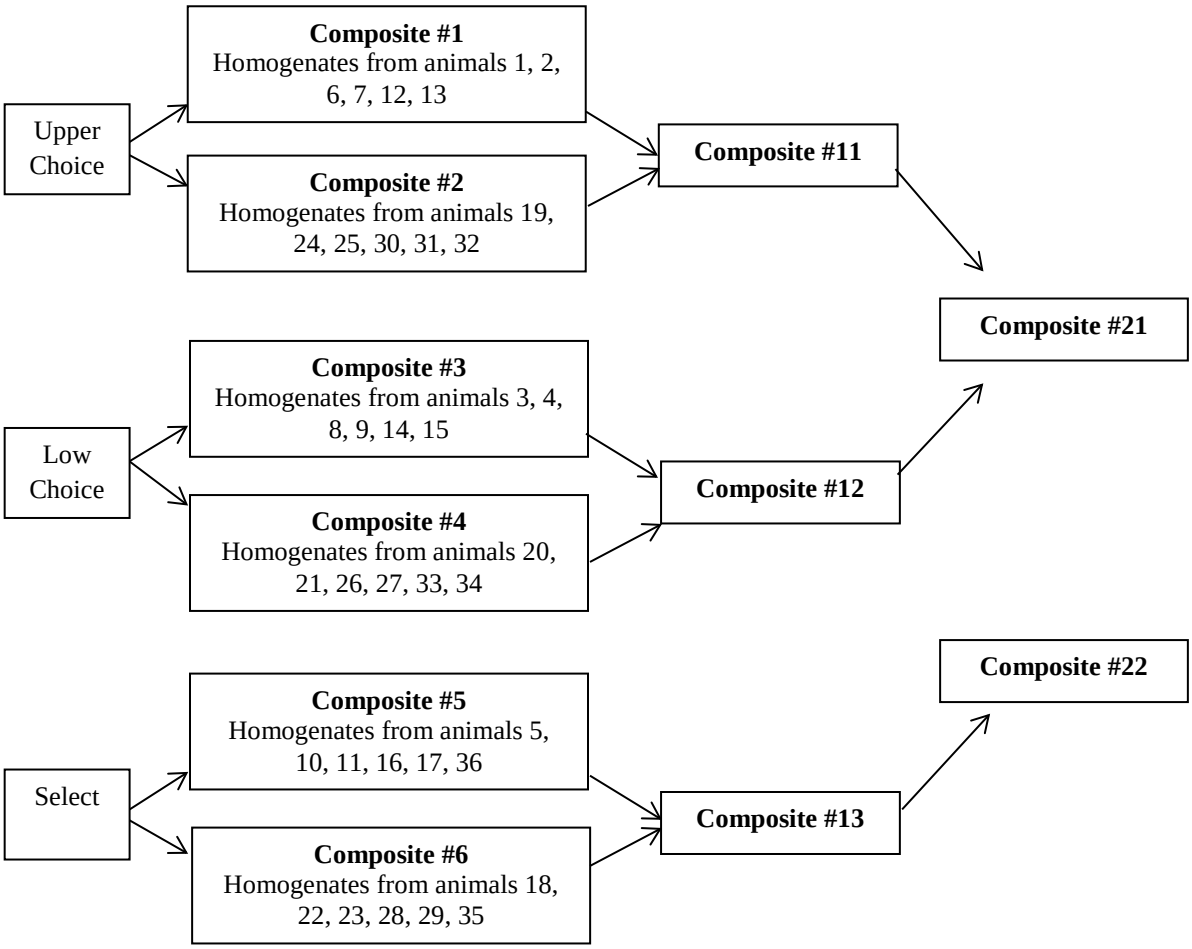

Figure 4.1. Overall compositing plan.

Table 4.1. Least squares means of the saturated[1] and monounsaturated[2] fatty acid content (g/100 g) of the separable lean from ten raw and six cooked U.S. retail beef cuts based on quality grade

	Saturated Fatty Acid, g						Monounsaturated Fatty Acid, g					
Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	Upper Choice	Low Choice	Choice	Select	SEM	All Grades
Number of carcasses	12	12	24	12	-	36	12	12	24	12	-	36
Raw												
Porterhouse steak, 0.32 cm	3.5^{a}	2.6^{b}	2.9^{z}	2.1^{by}	0.14	2.6	3.6^{a}	2.7^{b}	3.0^{z}	1.9^{cy}	0.08	2.6
T-bone steak, 0.32 cm	3.4	2.5	2.8	2.2	0.31	2.5	3.5^{a}	2.5^{ab}	2.8	2.0^{b}	0.28	2.5
Tenderloin roast/steak, 0 cm[3]	2.3^{a}	2.0^{ab}	2.1^{z}	1.7^{by}	0.01	2.0	2.3^{a}	2.0^{b}	2.1	1.6^{b}	0.15	1.9
Top loin steak, 0 and 0.32 cm[4]	2.6	2.5	2.5	2.1	0.30	2.3	2.7	2.6	2.7	2.1	0.32	2.4
Eye of round roast/steak, 0 cm[5]	1.2	1.1	1.1	1.0	0.084	1.1	1.3	1.2	1.2	1.0	0.12	1.1
Top round roast/steak, 0 cm[6]	1.5	1.2	1.3	0.9	0.16	1.1	1.6	1.2	1.4	0.9	0.17	1.2
Cooked[7]												
Porterhouse steak, 0.32 cm	4.8^{a}	4.2^{a}	4.4^{z}	3.5^{by}	0.14	4.0	5.0^{a}	4.3^{b}	4.5^{z}	3.3^{cy}	0.11	4.0
T-bone steak, 0.32 cm	5.1^{a}	4.4^{ab}	4.6	3.6^{b}	0.28	4.2	5.0^{a}	4.4^{ab}	4.6^{z}	3.3^{by}	0.28	4.1
Tenderloin roast, 0 cm	3.5^{a}	3.1^{ab}	3.3^{z}	2.6^{by}	0.15	3.0	3.5	3.1	3.3	2.4	0.28	2.9
Tenderloin steak, 0 cm	4.1^{a}	3.3^{b}	3.6^{z}	2.9^{by}	0.15	3.3	4.2	3.4	3.6	2.8	0.49	3.3
Top loin steak, 0 cm	4.0	3.8	3.9	2.7	0.35	3.4	4.2	4.0	4.1	2.6	0.41	3.5
Top loin steak, 0.32 cm	4.2	3.8	4.0	2.7	0.22	3.3	4.5	4.0	4.3	2.7	0.32	3.6

[1] Total SFA = Σ10:0, 12:0, 14:0, 15:0, 16:0, 17:0, 18:0, 20:0, 24:0.
[2] Total MUFA = Σ14:1, 16:1c, 17:1, 18:1c, 20:1.
[3] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[4] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[5] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[6] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[7] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-c] Within a row (Upper Choice, Low Choice, Select) and SFA/MUFA, least squares means lacking a common superscript letter differ ($P < 0.05$). Means without these superscripts are not significantly different.
[y, z] Within a row (Choice, Select) and SFA/MUFA, least squares means lacking a common superscript letter differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table 4.2. Least squares means of the polyunsaturated[1] and *trans*[2] fatty acid content (g/100 g) of the separable lean from ten raw and six cooked U.S. retail beef cuts based on quality grade

Retail cut, trim level	Polyunsaturated Fatty Acid, g						*Trans* Fatty Acid, g					
	Upper Choice	Low Choice	Choice	Select	SEM	All Grades	Upper Choice	Low Choice	Choice	Select	SEM	All Grades
Number of carcasses	12	12	24	12	-	36	12	12	24	12	-	36
Raw												
Porterhouse steak, 0.32 cm	0.35^{a}	0.33^{a}	0.34^{z}	0.25^{cy}	0.018	0.30	0.42^{a}	0.37^{a}	0.38^{z}	0.29^{by}	0.013	0.35
T-bone steak, 0.32 cm	0.37	0.29	0.32	0.26	0.037	0.29	0.36	0.31	0.33	0.29	0.090	0.31
Tenderloin roast/steak, 0 cm[3]	0.46	0.36	0.39	0.33	0.024	0.37	0.34	0.31	0.32	0.26	0.024	0.30
Top loin steak, 0 and 0.32 cm[4]	0.37	0.33	0.34	0.31	0.050	0.33	0.32	0.33	0.33	0.31	0.035	0.32
Eye of round roast/steak, 0 cm[5]	0.26	0.20	0.22	0.19	0.019	0.21	0.160	0.154	0.156	0.148	0.012	0.153
Top round roast/steak, 0 cm[6]	0.23	0.19	0.21	0.20	0.028	0.20	0.16	0.15	0.15	0.13	0.020	0.15
Cooked[7]												
Porterhouse steak, 0.32 cm	0.48	0.47	0.47	0.36	0.041	0.43	0.616	0.602	0.606	0.511	0.034	0.57
T-bone steak, 0.32 cm	0.49	0.48	0.48	0.39	0.040	0.45	0.65	0.63	0.64	0.57	0.049	0.61
Tenderloin roast, 0 cm	0.54	0.50	0.51	0.46	0.021	0.49	0.47	0.46	0.46	0.46	0.021	0.46
Tenderloin steak, 0 cm	0.63	0.50	0.54	0.45	0.041	0.51	0.58^{a}	0.48^{ab}	0.52	0.42^{b}	0.026	0.48
Top loin steak, 0 cm	0.48	0.40	0.42	0.34	0.042	0.39	0.52	0.52	0.52	0.42	0.043	0.48
Top loin steak, 0.32 cm	0.50	0.44	0.47	0.38	0.040	0.43	0.54	0.54	0.54	0.40	0.034	0.49

[1] Total PUFA = Σ18:2n-6, 18:3n-3, 20:2n-6, 20:3n-6, 20:4, 20:5n-3, 22:5n-3, 22:6n-3.
[2] Total *trans* = Σ16:1t, 6*t* 18:1, 9t 18:1, 10t 18:1, 11t 18:1, 18:2t.
[3] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[4] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[5] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[6] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[7] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-c] Within a row (Upper Choice, Low Choice, Select) and PUFA/*Trans*, least squares means lacking a common superscript letter differ ($P < 0.05$). Means without these superscripts are not significantly different.
[y, z] Within a row (Choice, Select) and PUFA/*Trans*, least squares means lacking a common superscript letter differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table 4.3. Least squares means of saturated, unsaturated, and *trans* fatty acids in raw retail cuts[1] from the loin and round as a percentage of total fatty acids (g/100 g fat)

	Porterhouse steak	T-bone steak	Tenderloin roast[2]	Top loin steak[3]	Eye of round roast[4]	Top round roast[5]
Number of carcasses	12	12	12	12	12	12
SFA[6], %						
Upper Choice	44.1	45.0	42.9	43.2	40.8[b]	42.0
Low Choice	43.7	44.2	43.5	42.7	42.0[ab]	42.2
Select	45.6	45.5	44.0	43.6	42.9[a]	43.1
SEM	0.95	0.95	0.95	0.95	0.35	0.35
MUFA[7], %						
Upper Choice	46.0	45.6	42.3	45.2	44.5	46.8[a]
Low Choice	44.6	44.9	42.2	45.8	44.9	44.8[a]
Select	42.3	42.9	40.8	43.6	42.8	41.4[b]
SEM	1.25	1.25	1.25	1.25	0.68	0.68
PUFA[8], %						
Upper Choice	4.5	4.8	8.6	6.2	9.1	6.6
Low Choice	5.5	5.3	7.7	5.7	7.4	7.3
Select	5.5	5.5	8.47	6.33	8.0	9.2
SEM	0.52	0.52	0.52	0.52	0.68	0.68
Trans[9], %						
Upper Choice	5.0	4.2	5.7	4.9	5.0[b]	4.3
Low Choice	5.7	5.2	6.1	4.5	5.3[b]	5.3
Select	6.2	5.8	6.2	6.1	5.8[a]	6.0
SEM	0.45	0.45	0.45	0.45	0.58	0.58
CLA[10], %						
Upper Choice	0.38	0.40	0.52	0.41	0.51	0.34
Low Choice	0.41	0.32	0.57	0.45	0.47	0.39
Select	0.34	0.32	0.57	0.45	0.48	0.25
SEM	0.063	0.063	0.063	0.063	0.073	0.073

[1] Porterhouse, T-bone, and top loin steaks were trimmed to an external fat level of 0.32 cm. Tenderloin, eye of round, and top round roasts were trimmed to an external fat level of 0 cm.
[2] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[3] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[4] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[5] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[6] Total SFA = Σ10:0, 12:0, 14:0, 15:0, 16:0, 17:0, 18:0, 20:0, 24:0.
[7] Total MUFA = Σ14:1, 16:1c, 17:1, 18:1c, 20:1.
[8] Total PUFA = Σ18:2n-6, 18:3n-3, 20:2n-6, 20:3n-6, 20:4, 20:5n-3, 22:5n-3, 22:6n-3.
[9] Total *trans* = Σ16:1t, 6*t* 18:1, 9t 18:1, 10t 18:1, 11t 18:1, 18:2t.
[10] Total CLA = Σc9, t11 18:2 and t10, c12 18:2.
[a, b] Within a cut and fatty acid, means without a common superscript differ ($P < 0.05$). Means without these superscripts do not differ ($P > 0.05$).

Table 4.4. Least squares means of saturated, unsaturated and *trans* fatty acids in cooked[1] retail cuts from the loin and round as a percentage of total fatty acids (g/100 g fat)

	Porterhouse steak, 0.32 cm	T-bone steak, 0.32 cm	Tenderloin roast, 0 cm	Tenderloin steak, 0 cm	Top loin steak, 0 cm	Top loin steak, 0.32 cm
Number of carcasses	12	12	12	12	12	12
SFA[2], %						
Upper Choice	44.4	45.1	43.6	43.1	43.8	43.2
Low Choice	43.9	44.1	43.5	43.2	43.7	43.3
Select	45.3	46.1	44.3	44.3	44.5	43.6
SEM	1.20	1.20	1.20	1.20	1.20	1.20
MUFA[3], %						
Upper Choice	45.5	44.7	43.8	43.9	45.3	46.2
Low Choice	45.0	44.7	43.3	44.0	45.8	45.4
Select	43.3	41.8	40.9	42.2	42.9	43.8
SEM	1.56	1.56	1.56	1.56	1.56	1.56
PUFA[4], %						
Upper Choice	4.4	4.4	6.7	6.8	5.2	5.1
Low Choice	4.9	4.8	6.9	6.5	4.6	5.0
Select	4.7	5.0	7.9	7.0	5.7	6.2
SEM	0.54	0.54	0.54	0.54	0.54	0.54
Tran[5], %						
Upper Choice	5.2[b]	5.4[b]	5.4[b]	5.7	5.2[b]	5.2
Low Choice	5.9[ab]	6.0[ab]	5.8[ab]	5.8	5.4[b]	5.8
Select	6.3[a]	6.8[a]	6.4[a]	6.0	6.4[a]	6.0
SEM	0.30	0.30	0.30	0.30	0.30	0.30
CLA[6], %						
Upper Choice	0.42	0.39	0.48	0.55	0.55	0.39
Low Choice	0.40	0.40	0.52	0.51	0.56	0.42
Select	0.36	0.39	0.58	0.56	0.58	0.44
SEM	0.073	0.073	0.073	0.073	0.073	0.073

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[2] Total SFA = Σ10:0, 12:0, 14:0, 15:0, 16:0, 17:0, 18:0, 20:0, 24:0.
[3] Total MUFA = Σ14:1, 16:1c, 17:1, 18:1c, 20:1.
[4] Total PUFA = Σ18:2n-6, 18:3n-3, 20:2n-6, 20:3n-6, 20:4, 20:5n-3, 22:5n-3, 22:6n-3.
[5] Total *trans* = Σ16:1t, 6*t* 18:1, 9t 18:1, 10t 18:1, 11t 18:1, 18:2t.
[6] Total CLA = Σc9, t11 18:2 and t10, c12 18:2.
[a, b] Within a cut and fatty acid, means without a common superscript differ ($P < 0.05$). Means without these superscripts do not differ ($P > 0.05$).

Table 4.5. Least squares means of the cholesterol content (mg/100 g) of the separable lean from ten raw and six cooked U.S. retail beef cuts based on quality grade

Retail cut, trim level	Upper Choice	Low Choice	Choice	Select	SEM	All Grades
Number of carcasses	12	12	24	12	-	36
Raw						
Porterhouse steak, 0.32 cm	59	58	59	57	1.8	58
T-bone steak, 0.32 cm	59.3	58.9	59.0	59.1	0.85	59.1
Tenderloin roast/steak, 0 cm[1]	57	62	60	62	1.9	61
Top loin steak, 0 and 0.32 cm[2]	55.5	59.5	58.1	62.1	2.3	59.7
Eye of round roast/steak, 0 cm[3]	60	57	58	62	6.0	60
Top round roast/steak, 0 cm[4]	63	61	61	63	3.0	62
Cooked[5]						
Porterhouse steak, 0.32 cm	81	86	85	78	4.0	82
T-bone steak, 0.32 cm	84.2	79.5	81.0	83.1	2.5	81.9
Tenderloin roast, 0 cm	76	85	82	85	2.4	84
Tenderloin steak, 0 cm	100	90	93	93	6.9	93
Top loin steak, 0.32 cm	76.3	82.2	80.3	80.2	2.3	80.2

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

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CHAPTER V

NUTRIENT DATABASE IMPROVEMENT PROJECT: VITAMIN AND MINERAL COMPOSITION OF RAW AND COOKED RETAIL CUTS FROM THE BEEF LOIN AND ROUND

SUMMARY

For domestic and international consumers, beef is an important source of many vitamins and minerals that are essential for health. The objective of this study was to analyze the vitamin and mineral composition of ten beef loin and round cuts to update the nutrient data in the USDA National Nutrient Database for Standard Reference. Beef short loins, strip loins, tenderloins, inside rounds, and eye of rounds (IMPS # 173, 175, 190A, 169A, and 171C) were collected from 72 carcasses to represent the national consist and shipped to three university meat laboratories for storage, retail fabrication, compositing, and raw/cooked analysis of nutrients. Composite samples were analyzed for vitamin and mineral composition. Results from the cooked beef loin samples indicate that beef is a good source of iron, vitamin B2, and phosphorus, and an excellent source of selenium, zinc, and vitamins B3, B6, and B12.

INTRODUCTION

Beef is an important source of micronutrients in both American and international diets (Williamson et al., 2005; Williams, 2007; Zanovec et al., 2010; Nicklas et al., 2012). In the American diet, beef is one of the top five food sources of the following vitamins and minerals: B-vitamins, choline, selenium, zinc, and iron (Cotton et al., 2004; Zanovec et al., 2010; Nicklas et al., 2012). A recent dietary recall survey on nutrient intake conducted through the National Health and Nutrition Examination Survey (NHANES) revealed Americans who consumed lean beef had significantly higher intakes of zinc, iron, vitamins B6 and B12, potassium, and

phosphorus than non-beef consumers (Nicklas et al., 2012). These studies indicated that micronutrient content of beef is important to help consumers obtain an adequate quantity of important vitamins and minerals.

The USDA Nutrient Database for Standard Reference (SR) provides the nutrient content data used in epidemiological studies to determine the micronutrient status of different American diets. In addition, the data in the SR is used to develop appropriate diets in randomized, control studies to ensure participants are not deficient in any nutrient. While the SR is considered one of the best food composition databases in the world, much of the nutrient data related to retail beef cuts is becoming outdated due to changes in production practices, fabrication techniques, cooking methods, and marketing strategies. In addition, with the implementation of the Nutrition Labeling of Single-Ingredient Products and Ground or Chopped Meat and Poultry Products; Final Rule (USDA-FSIS, 2010), it has become imperative that nutrient content data be updated to reflect the current retail and foodservice beef supply. Currency of the data will allow for the most accurate nutrient data on beef nutrient labels in the retail meat case, which will provide opportunity for on-pack nutrient claims. To accomplish these goals, the National Cattlemen's Beef Association and the USDA Agricultural Research Service collaborated to update the nutrient composition data of current retail beef cuts. The objective of this study was to determine the vitamin and mineral content of raw and cooked retail beef loin and round cuts.

MATERIALS AND METHODS

Carcass selection, retail cut fabrication, cooking, dissection, and homogenization procedures were described previously in Chapter III.

Carcass and Subprimal Selection

Seventy-two beef carcasses from seven different packing plants in six different regions, (Green Bay, WI; Greeley, CO; Dodge City, KS; Tolleson, AZ; Plainview, TX; Omaha, NE; Corpus Christi, TX) of the Unites States were selected to represent the following characteristics: 67% USDA Choice, 33% USDA Select, 50% USDA Yield Grade 2, 50% USDA Yield Grade (YG) 3, 67% steers, 33% heifers; and 12.5% dairy, 87.5% non-dairy. Only A-maturity carcasses with hot carcass weights between 299 to 411 kg were selected for the study.

After selection, carcasses were fabricated according to the plant protocol to obtain the following subprimals: beef loin, short loin (IMPS #173, beef loin, strip loin, bone in (IMPS #175), beef loin, tenderloin, full, side muscle off, defatted (IMPS #190), beef round, eye of round (IMPS #171C), and beef, round, top round (IMPS #169A). After collection, subprimals were shipped via refrigerated truck to one of the three collaborating universities and stored in the absence of light at 0 to 4^{o}C until fabrication.

Retail Cut Fabrication

Between 14 to 21 d postmortem, subprimals were fabricated into pre-identified retail cuts. During retail cut fabrication, the short loin (IMPS #173) was fabricated into porterhouse steaks and T-Bone steaks with 0.32 cm external fat. The strip loin (IMPS #175) was fabricated into top loin steaks with 0 or 0.32 cm external fat. The tenderloin (IMPS#190), eye of round (IMPS #171C), and top round (IMPS #169A) were fabricated into steaks and roasts with 0 cm external fat. On the date of fabrication, retail cuts were individually identified, vacuum packaged, and frozen (-20^{o}C) until cooked or dissected as raw product.

Cooking of Retail Cuts

Before cooking, retail cuts were tempered in a single layer at 0 to 4°C for 24 or 48 h. No retail cuts from the round were cooked. Two cooking methods were utilized: grilling and roasting. Cuts assigned to grilling were: porterhouse steaks, T-Bone steaks, tenderloin steaks, and top loin steaks (0 cm and 0.32 cm). A Salton two-sided electric grill (Model GRP99, Salton Inc., Lake Forest, IL) was used to cook steaks to an internal temperature of 70^{o}C.

The tenderloin roast was the only cut assigned to roasting. Each individual tenderloin roast was placed in a non-stick anodized aluminum roasting pan with rack (Calphalon Corp. Toledo, OH) and roasted until an internal temperature of 60°C was obtained. Immediately after cooking, all steaks were placed on wire racks and allowed to chill uncovered, at refrigeration temperatures (0 to 4°C) for at least 12 h before cooked dissection.

Retail Cut Dissection

Standardized protocols were used for the dissection of raw and cooked retail cuts. Samples were tempered in a single layer at 0 to 4^{o}C for 24 to 48 h (raw samples) or 12 to 24 h (cooked samples) before dissection. Steaks and roasts were dissected to yield the following components:

- Refuse (waste) – defined as all bone and heavy connective tissue.
- Separable lean – included all muscle, intramuscular fat and any light connective tissue considered edible.
- External fat – defined as the adipose tissue located on the outer surface of the cut and above the bridge of the muscles.

- Seam fat – included all fat deposited between muscles in a cut and may extend to the outer portion of the cut as a result of fabrication. After recording the lip fat weight, the lip fat was added to the seam fat for homogenization.
- Lip Lean (top loin steaks only) – Included all lean from the lip. The lip was defined as the portion ventral to the *Longissimus dorsi*.
- Lip fat (top loin steaks only) – Included all fat from the lip region as previously defined.

Retail Cut Homogenization

Due to the sensitivity of B vitamins and other nutrients and to prevent contamination, homogenization and aliquoting procedures were performed in the absence of direct light and powder-free nitrile gloves were worn. All lean samples were homogenized on the same day that they were dissected. Samples of the same retail cut that came from the same individual animal were combined for homogenization. Following dissection, each retail cut was cut into 2.5-cm^3 pieces and the pieces were submerged in liquid nitrogen until all pieces were completely frozen. A stainless steel spoon was used to transfer the frozen samples into a 7-quart (6.62-L) Robot Coupe BLIXER 6V (Robot Coupe USA Inc., Ridgeland, MS) and blended to form a finely-powdered homogenate. Each sample was blended for approximately 10 s on low speed (1500 rpm) and 30 s on high speed (3500 rpm). After the sample was homogenized, 450 g of the sample was shipped to Texas Tech University (TTU) (Lubbock, TX) for central compositing of individual cuts and national nutrient analysis.

Retail Cut and Fat Compositing

To conduct national nutrient analysis, individual cuts from each carcass from all universities were combined to form a six, three, and national level aggregate. The six-level composite samples contained lean from six individual carcasses representing each quality grade

(Upper Choice, Low Choice, and Select). The six-level composite samples were used to make the three-level composite samples. Twelve carcasses were represented in each three-level composite sample. The national composite represented the two USDA quality grades (Choice and Select).

The amount of sample originating from each individual carcass was equal among all carcasses and was specific to the nutrient analysis to be performed for the respective cut. Samples for nutrient analysis were aliquoted into Whirl-Pak® bags in the presence of dry ice and then shipped to the respective laboratory for nutrient analysis.

Nutrient Analysis

Selenium, riboflavin, niacin, vitamin B6, vitamin B12, calcium, magnesium, potassium, iron, sodium, zinc, copper, manganese, and phosphorus analysis were performed on: cooked beef, loin, porterhouse steak,; cooked beef, loin, T-bone steak; cooked beef, loin, top loin steak, boneless, 0.32 cm trim; cooked beef, loin, tenderloin roast; raw beef, round, eye of round roast; and raw beef, round, top round roast. Thiamin, pantothenic acid, choline, 25-hydroxy vitamin D3, and vitamin E analysis were performed on: cooked and raw beef, loin, top loin steak, boneless, 0.32 cm trim and raw beef, round, top round roast. Figure 5.1 contains information on nutrient analysis by composite level.

ICP Mineral Analysis

Inductively coupled plasma mass spectrometry (ICP) minerals (calcium, magnesium, potassium, sodium, iron, zinc, copper, manganese) were quantified in the three-level composite samples using the AOAC Official Method 985.35 and USDA wet ashing procedure. Phosphorus was analyzed using a colormetric method (AOAC Official Method 2.019, 2.095, and 7.098).

Selenium analysis

Selenium content of three-level composite samples was performed by Covance Laboratory (Madison, WI) using AOAC 986.15 hydride generation method (AOAC, 2005). Briefly, samples were digested with perchloric acid prior to reduction with hydrochloric acid. The samples were then reacted with sodium borohydride to produce the volatile selenium hydride, which was measured by atomic absorption spectroscopy. The quantitation limit for this analysis was 30 ppb.

B-Vitamins

The following B-vitamins were analyzed by Covance Laboratories (Madison, WI) at the six-level composite: B12, B6, riboflavin, and niacin. The AOAC methods utilized in the analysis of each vitamin were: Vitamin B-12- AOAC 952.20 and 960.46; Niacin- AOAC 944.13 and 960.46; Vitamin B6- AOAC 961.15; Riboflavin- AOAC 960.46 and 940.3. Thiamin and pantothenic acid were analyzed by Covance Laboratories (Madison, WI) at the national composite level. The AOAC methods utilized in the analyses were: Thiamin- AOAC 942.23, 953.17, and 957.17; Pantothenic acid- AOAC 945.74 and 960.46.

Total Choline

Total choline was measured at the national composite level for cooked and raw beef, loin, top loin steaks, boneless, 0.32 cm trim and raw beef, round, top round roasts by the University of North Carolina, Chapel Hill by isotope dilution mass spectrometry (Koc et al., 2002).

Vitamin E

Vitamin E content was measured at the six composite level for cooked and raw beef, loin, top loin steaks, boneless, 0.32 cm trim and raw beef, round, top round roasts by Craft

Technologies (Wilson, NC) using HPLC with a normal phase column, and UV detection with external calibration, and internal standard recovery post analysis.

Vitamin D and 25-hydroxy

Vitamin D3 and 25-hydroxy vitamin D3 content was determined for the national composite samples of cooked and raw beef, loin, top loin steaks, boneless, 0.32 cm trim and raw beef, round, top round roasts. Vitamin D analyses were performed by Covance Laboratories (Madison, WI) using a liquid chromatography/mass spectrophotometry method (Huang et al., 2009).

Statistical Design and Analysis

Experimental design

The experimental design utilized for this study was described previously in Chapter III. For six composite data, a mean for each composite was computed for analysis averaging across multiple analytical values. The model defined Quality Grade as fixed and the residual variation as random. Weighted least squares means were computed so that design percentages for quality grades were achieved. Compositing proportions were used to achieve the desired mix of Yield Grades, sex classes, and approximate mix of cattle type.

For three-level and national composite data, a mean for each composite was computed by averaging across multiple analytical values. Statistical analysis was not possible because these composites were not replicated. Compositing proportions were used to achieve the desired mix of Yield Grades, sex classes, and approximate mix of cattle type.

RESULTS AND DISCUSSION

Statistical analysis could only be performed on B-vitamins analyzed at the six-level composite (Tables 5.1 and 5.2). Quality Grade did not influence ($P > 0.05$) B vitamin content of

retail cuts. The lack of difference between Quality Grades was expected since B vitamins are not stored in the lipid portion of a steak or roast and should not be largely impacted by a change in fat content. B vitamin content was impacted ($P < 0.05$) by cut. For raw loin retail cuts, porterhouse steaks had greater ($P < 0.05$) vitamin B6 content; however, this difference was not observed in the cooked cuts. Raw and cooked tenderloin roasts/steaks had the greatest ($P < 0.05$) vitamin B2 and B12 content. Raw and cooked top loin steaks had the greatest ($P < 0.05$) vitamin B3 content. While B vitamin content did differ among cuts, each cut was still a good source of many essential vitamins and minerals.

Table 5.2 contains the Reference Dietary Intake (RDI) for each vitamin and mineral, as well as the Percent Reference Daily Intake provided for each nutrient by beef cuts according to the All Grades data. According to the Food and Drug Administration, a food is considered a "good source" of a nutrient if a single serving contains 10 to 19% of the Daily Value (DV) for that nutrient based on a 2000 calorie diet. Foods containing 20% or more of the DV for a nutrient are considered an "excellent source". The Daily Value for a specific vitamin or mineral is based off of Reference Daily Intake (RDIs) which are the daily intake level of a nutrient that is considered to be sufficient for approximately 98% of health Americans. The current study revealed that the cooked loin cuts in the present study are a good source of iron, vitamin B2, and phosphorus and an excellent source of selenium, zinc, and vitamins B3, B6, and B12.

Over 30% of the world's population suffers from iron deficiency making it the most prevalent deficiency in the world (WHO, 2013). In the United States, 9 to 16% of adolescents and women of childbearing age have iron deficiency (CDC, 2002). Beef contains the most bioavailable type of iron, heme-iron. Approximately 20 to 30% of heme-iron is absorbed in the body versus 7% of non-heme iron provided by plant sources. In the study, cooked loin cuts

contained between 2.6 to 3.7 mg iron per 100 g lean tissue. Due to the high iron content, beef is considered the third best source of iron in the United States, providing approximately 9% of the iron consumed in the American diet (Cotton et al., 2004; Nicklas et al., 2012).

Riboflavin or vitamin B2 is essential for the synthesis of flavocoenzymes (FAD, FMN), which function in oxidation-reduction reactions involved in the catabolism of glucose, fatty acids, ketone bodies, and amino acids. Beef is the fourth best source vitamin B2 in the American diet (Cotton et al., 2004). In the present study, cooked loin cuts contained between 0.21 to 0.40 mg/100 g lean tissue. Beef is the third best source phosphorus in the American diet (Cotton et al., 2004) and cooked cut phosphorus content in the current study ranged from 208 to 259 mg/100 g lean tissue.

Beef is the number one source of zinc and vitamin B12 in the American diet. In the current study, cooked retail loin cuts provided 3.7 to 4.8 mg zinc and 1.9 to 4.2 µg vitamins B12 per 100 g lean tissue. Zinc is required for the activity of many enzymes and metaloenzymes in the human body, and has a non-enzymatic role in regulating genes through the zinc fingers. Beef provides 23% of the zinc consumed in the diet (Nicklas et al., 2012). Vitamin B12 is needed for fatty acid metabolism in the formation of the myelin sheath around nerves and for the formation of healthy red blood cells. Beef provides 27% of the vitamin B12 in the diet (Nicklas et al., 2012). Additionally, beef is the number two source of selenium and number three source of vitamins B3 and B6 (Cotton et al., 2004). Results from the current study determined that retail cuts from the beef loin and round contain between 25 to 32 µg selenium, 5 to 8 mg vitamin B3, and 0.6 to 0.8 mg vitamin B6 per 100 g lean tissue. Desimone et al. (2013) also reported similar selenium and vitamin B12 values in Beef Alternative Merchandising (BAM) cuts from the beef rib, strip loin, and sirloin. Cooked loin cuts in the present study are not a good source of copper,

calcium, magnesium, manganese, potassium, and sodium since these cuts provide less than 10% of the DV in one serving.

With the implementation of Nutrition Labeling of Single-Ingredient Products and Ground or Chopped Meat and Poultry Products; Final Rule (USDA-FSIS, 2010), data from this study will be used to develop accurate nutrition labels for retail beef cuts. Production practices change over time, potentially resulting in a change in the nutrient content of beef products. As a result, it is important to re-analyze the nutrient content of beef products on a regular basis to make sure the information available in the SR is representative of the current beef supply. Compared to similar retail cuts in the previous SR (USDA-ARS, 2011), retail cuts from this study had greater calcium, selenium, and vitamins B2, B3, B6, and B12. Internationally, this information will be used by countries that currently do not have food composition databases (Merchant and Dehghan, 2006). Compared to similar cuts in the Australia, United Kingdom, and Canadian databases, the cuts in this study had greater calcium and selenium content and less magnesium and potassium content (DOH, 2002; FSANZ, 2010; Health-Canada, 2010). The retail beef cuts from the current study had similar nutrient content for all other reported vitamins and minerals, except for B vitamins. Australia retail beef cuts had less vitamins B2, B3, and B6 than the cuts in the current study. Numerous cattle production practices, such as forage type, slaughter age, length of time on feed, as well as, nutrient analysis method may have caused differences in values between the various databases.

Conclusions

Results of this study provide both domestic and international consumers with an accurate description of the micronutrient content of retail beef cuts based on current production practices in the United States. These data highlight that micronutrient content within a retail beef cut

remains the same regardless of Quality Grade. In addition, these data show that cooked retail beef cuts from the loin and round are a good source of good source of iron, vitamin B2, and phosphorus and an excellent source of selenium, zinc, and vitamins B3, B6, and B12. Beef loin and round retail cuts serve as an important source of bioavailable minerals and vitamins for a healthy diet.

Analytical Procedure	Unit to Be Analyzed		
	6 Composite	3 Composite	National Composite
ICP Minerals		X[2]	
Selenium		X[2]	
B-Vitamins (B2, B3, B6, B12)	X[2]		
B-Vitamins (B1, B5)			X[3]
Total Choline			X[3]
Vitamin E	X[2]		
25-Hydroxy Vitamin D3			X[3]

Figure 5.1. Nutrient analysis by beef retail cut and composite level

[1] ICP minerals included iron, zinc, magnesium, manganese, sodium, potassium, copper, and phosphorus.

[2] ICP minerals, selenium, and vitamins B2, B3, B6, and B12 analysis performed on: cooked beef, loin, porterhouse steak, cooked beef, loin, T-bone steak, cooked beef, loin, top loin steak, boneless, 0.32 cm trim, cooked beef, loin, tenderloin roast., raw beef, round, eye of round Roast, and raw beef, round, top round roast.

[3] Vitamin B1 and B5, choline, and 25-hydroxy vitamin D3 analysis performed on: cooked beef, loin, top loin steak, boneless, 0.32 cm trim, and raw beef, round, top round roast.

Table 5.1. Vitamin and mineral composition of separable lean (g/100g) from all grades[1] raw loin and round retail cuts

Nutrient, unit/100g	Raw loin cuts, trim level					Raw round cuts, trim level		
	Porterhouse steak, 0.32 cm	T-Bone steak, 0.32 cm	Tenderloin roast/steak[2], 0 cm	Top loin steak[3], 0 cm and 0.32 cm	SEM	Eye of round roast/steak[4], 0 cm	Top round roast/steak[5], 0 cm	SEM
Three-level composite[6]								
Calcium, mg	18.5	21.3	13.5	14.6	-	12.8	13.1	-
Copper, mg	0. 065	0.058	0.063	0.044	-	0.042	0.048	-
Iron, mg	2.07	1.66	2.50	1.84	-	1.45	2.34	-
Magnesium, mg	11.0	11.1	12.1	11.7	-	11.8	12.2	-
Manganese, mg	0.0033	0.0026	0.0070	0.0020	-	0.0014	0.0038	-
Phosphorus, mg	206	200	215	207	-	222	220	-
Potassium, mg	274	267	289	284	-	319	313	-
Selenium, µg	22.0	22.8	20.4	21.5	-	22.6	22.2	-
Sodium, mg	51.5	42.2	44.5	45.8	-	52.7	54.1	-
Zinc, mg	3.58	3.88	3.26	3.72	-	3.42	3.71	-
National level composite[7]								
Choline, mg	-	-	-	58.3	-	-	64.8	-
Vitamin B1, mg	-	-	-	0.056	-	-	0.064	-
Vitamin B5, mg	-	-	-	0.37			0.36	-
25 Hydroxy Vitamin D3, µg	-	-	-	0.240	-	-	0.358	-
Six-level composite[8]								
Vitamin B2, mg	0.26[b]	0.22[c]	0.32[a]	0.21[c]	0.011	0.18[b]	0.23[a]	0.005
Vitamin B3, mg	5.4[b]	5.8[b]	4.8[c]	6.7[a]	0.17	6.7[a]	6.5[a]	0.28
Vitamin B6, mg	0.69[a]	0.64[b]	0.61[b]	0.58[b]	0.019	0.64[a]	0.64[a]	0.020
Vitamin B12, µg	1.95[b]	1.81[b]	3.53[a]	1.78[b]	0.090	1.84[a]	1.64[b]	0.090
Vitamin E, mg	-	-	-	0.22	0.007	-	0.22	0.005

[1] All grades is a weighted mean representing 2/3 Choice and 1/3 Select, resulting in a mean representing 1/5 Upper Choice, 2/5 Lower Choice, and 2/5 Select.
[2] Weighted means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[3] Weighted means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[4] Weighted means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[5] Weighted means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[6] Differences between cuts were not tested for three-level composite samples.
[7] Nutrient values were only determined for the beef, loin, top loin steak, 0.32 cm trim and beef, round, top round roast, 0 cm trim for national level composite samples.
[a-c] Within a row (cut) and loin/round for six-level composite samples, means without a common superscript differ ($P < 0.05$).

Table 5.2. Vitamin and mineral composition of separable lean (g/100g) of cooked loin retail cuts determined by all grades[1] data

Nutrient, unit/100g	RDI[2]	Porterhouse steak, 0.32 cm	% RDI[3]	T-Bone steak, 0.32 cm	% RDI[3]	Tenderloin roast/steak[4], 0 cm	% RDI[3]	Top loin steak[5]	% RDI[3]	SEM
Three-level composite[6]										
Calcium, mg	1000	19.3	1.9	18.4	1.8	13.3	1.4	12.8	1.3	-
Copper, mg	2	0.073	3.7	0.073	3.6	0.091	3.2	0.074	3.7	-
Iron, mg	18	3.22	17.9	3.57	19.8	3.22	13.9	2.59	14.4	-
Magnesium, mg	400	22.8	5.7	21.4	5.4	18.2	3.0	22.5	5.6	-
Manganese, mg	2	0.0037	0.18	0.0036	0.18	0.0089	0.35	0.0037	0.19	-
Phosphorus, mg	1000	224	22.4	219	21.9	255	21.5	229	22.9	-
Potassium, mg	3500	291	8.3	290	8.3	350	8.3	299	8.5	-
Selenium, µg	70	28.2	40.3	29.3	41.9	25.1	39.6	27.7	39.6	-
Sodium, mg	2400	67.8	2.8	66.7	2.8	56.3	1.9	54.0	2.3	-
Zinc, mg	15	4.67	31.1	4.61	30.7	4.19	21.7	4.71	31.4	-
National level composite[7]										
Choline[8], mg	-	-	-	-	-	-	-	68.0	-	-
Vitamin B1, mg	1.5	-	-	-	-	-	-	0.062	4.2	-
Vitamin B5, mg	10	-	-	-	-	-	-	0.35	3.5	
25 Hydroxy Vitamin D3, µg	15	-	-	-	-	-	-	0.23	1.5	-
Six-level composite[9]										
Vitamin B2, mg	1.7	0.26[b]	15.3	0.25[b]	14.7	0.40[a]	23.2	0.22[c]	13.0	0.009
Vitamin B3, mg	5.0	6.0[a]	30	6.1[a]	30.5	5.6[b]	28.0	7.3[a]	36.5	0.19
Vitamin B6, mg	2	0.69[a]	34.5	0.76[a]	37.9	0.69[a]	34.5	0.72[a]	36.0	0.016
Vitamin B12, µg	6	2.16[b]	36	1.96[b]	32.7	4.09[a]	68.3	1.96[b]	32.7	0.087
Vitamin E, mg	30	-	-	-	-	-	-	0.22	0.73	0.019

[1] All grades is a weighted mean representing 2/3 Choice and 1/3 Select, resulting in a mean representing 1/5 Upper Choice, 2/5 Lower Choice, and 2/5 Select.
[2] Reference daily intakes (RDI) dietary allowance (RDA) is the daily intake level of a nutrient that is considered to be sufficient to meet the requirements of 97-98% of healthy individuals in the United States.
[3] % RDI: Percent Reference Daily Intake. The % RDI is based on a 2,000 calorie intake and is calculated as the average % DV across all cuts.
[4] Weighted means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[5] Weighted means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[6] Differences between cuts were not tested for three-level composite samples.
[8] Reference daily intake for choline has not been determined.
[9] Nutrient values were only determined for the beef, loin, top loin steak, 0.32 cm trim and beef, round, top round roast, 0 cm trim for national level composite samples.
[a-c] Within a row (cut) and loin/round for six-level composite samples, means without a common superscript differ ($P < 0.05$).

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CHAPTER VI

EFFECTS OF DIFFERENCES IN CARCASS MATURITY ON EATING QUALITY OF BEEF PRODUCED BY GRAIN-FINISHED STEERS AND HEIFERS THAT HAVE BEEN CLASSIFIED AS LESS THAN 30 MONTHS USING BIRTH RECORDS OR DENTITION

SUMMARY

Cattle that produce carcasses classified as B maturity or older currently receive substantial price discounts regardless of sensory attributes. This study investigated the effect of physiological maturity on LM sensory attributes, shear force measurements, and collagen content in fed steers (n = 198) and heifers (n = 252) classified as 30 months of age (MOA) or younger using dentition. Carcasses were selected to represent 2 maturity groups and 3 marbling categories within each maturity group. Maturity groups included A^{00} to A^{99} overall maturity (A) and B^{00} to C^{99} overall maturity (B-C); marbling categories included Slight (SL), Small (SM), and $Modest^{00}$ or greater (MT+). Strip loin samples were collected from both sides of the carcass. One sample was used for Warner-Bratzler shear force (WBSF) and slice shear force (SSF) analysis and another sample was used for trained sensory panel and collagen analysis. The statistical model for sensory panel ratings and longissimus shear force measurements included the random effects of pair within marbling category and sex, block, and collection day and the fixed effects included maturity group, marbling category, and the respective interaction. Maturity group had no effect ($P > 0.05$) on WBSF, SSF, or sensory panel ratings. Total collagen content was not different ($P > 0.05$) between maturity groups and marbling category, except for in the MT+ marbling category where B-C maturity carcasses had greater ($P < 0.05$) total collagen content. Percent heat soluble collagen was greater in B-C maturity carcasses than in A maturity carcasses. As marbling category increased, sensory tenderness, juiciness, meaty/brothy flavor, and butter/beef fat flavor

increased ($P < 0.05$) while bloody/serumy flavor, livery/organy flavor, WBSF, and SSF decreased ($P < 0.05$). In grain-finished steers and heifers classified as less than 30 MOA by dentition, physiological maturity did not affect sensory attributes or shear force measurements, suggesting that current price discounts may be unjustified.

INTRODUCTION

Carcasses from all cattle processed in U.S. federally inspected beef plants currently are segregated into 2 age groups based on dentition. Carcasses from cattle with fewer than 3 permanent incisors **(PI)** are classified as less than 30 months of age **(MOA)**, whereas carcasses from cattle with 3 or more PI are classified as 30 MOA or older. Carcasses in these 2 age groups are graded and fabricated separately.

When beef carcasses are presented for quality grading, USDA graders examine indicators of physiological maturity (i.e., size and shape of the ribs and ossification of the bones and cartilages along the vertebral column of the split carcass, together with the color and texture of the LM at the 12th rib) and classify each carcass into 1 of 5 maturity groups designated A through E (USDA, 1997). Approximate ages corresponding to each maturity classification are: A = 9 to 30 mo, B = 30 to 42 mo, C = 42 to 72 mo, D = 72 to 96 mo, and E = more than 96 mo. Occasionally, however, cattle younger than 30 MOA (based on actual age or dentition) do not produce A maturity carcasses because they exhibit premature skeletal ossification, which causes them to be classified as B maturity or older (Tatum, 2011).

Studies conducted to determine the relationship between physiological maturity and beef tenderness across the broad spectrum of cattle and beef carcasses produced in the U.S. suggest that progressive increases in USDA maturity (from A through E) are associated with greater beef toughness (Smith et al., 1982; Smith et al., 1988; Hilton et al., 1998). However, research has

failed to demonstrate a consistent relationship between carcass maturity and beef tenderness when comparisons among maturity groups are restricted to include only carcasses produced by grain-finished steers and heifers (Miller et al., 1983; Field et al., 1997).

Results of the 2011 National Beef Quality Audit revealed that 7.2% of the U.S. fed steer and heifer population produced carcasses that were classified as B maturity or older (Moore et al., 2012). Currently, carcasses classified as B or older receive substantial price discounts (USDA, 2013), yet if beef from these "more mature" carcasses has sensory attributes comparable to those of beef produced by A maturity carcasses, then any price discount is unjustified. This study was conducted to compare sensory properties of beef from A maturity and B maturity or older carcasses produced by grain-finished steers and heifers classified as less than 30 MOA.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not obtained because no live animals were involved in this study. The experimental sample consisted of chilled beef carcasses (n = 450) selected at 2 commercial fed-beef processing plants located in Colorado and Nebraska.

Carcass Selection

Carcass selection began 13 August 2012 and concluded 6 November 2012. Sampling for the experiment was restricted to include only beef carcasses produced by cattle that had been classified as less than 30 MOA based on dentition or age verification. Carcasses were selected to represent 2 maturity groups and 3 marbling categories within each maturity group. Maturity groups included A^{00} to A^{99} overall maturity (**A**) and B^{00} to C^{99} overall maturity (**B-C**); marbling categories included Slight (**SL**), Small (**SM**), and $Modest^{00}$ or greater (**MT+**).

On each sampling day, carcasses were pre-selected based on a cursory assessment of carcass maturity characteristics and the official marbling score which was determined using an

on-line, USDA-approved instrument grading system (E+V Technology, Oranienburg, Germany). Pre-selected carcasses then were transferred to stationary rails for official maturity classification by USDA graders and further data collection by the research team. Each carcass was evaluated by a USDA grader who determined skeletal, lean, and overall maturity scores. Final selection of carcasses for inclusion in the study was based on the grader's overall maturity score and the instrument-based marbling score. Each carcass selected to represent the B-C maturity group was paired with an A-maturity carcass of the same sex and marbling score (± 30 marbling units). When possible, pairs were selected from the same slaughter lot.

Colorado State University personnel recorded the following information for each selected carcass: HCW, subcutaneous fat thickness at the 12^{th} rib, adjusted preliminary yield grade, estimated KPH fat percentage, sex classification (heifer or steer), presence or absence of an "A stamp", and presence or absence of an Age and Source Verified tag, which indicated that age verification records were available for that carcass. Instrument measurements of LM area were retrieved from the data archives at each plant and were used to calculate yield grade.

Within 1 h of carcass ribbing, L* a*, and b* values were measured (Hunter Lab Miniscan, Model 45/O-S, Hunter Associates Laboratory Inc., Reston, VA) in triplicate on the exposed surface of the LM at the 12^{th}-13^{th} rib interface. Objective color measurements obtained from the left and right sides of each carcass were averaged to obtain a single L* (0 = black; 100 = white), a* (negative number = green; positive number = red), and b* (negative number = blue; positive number = yellow) value for the carcass. The spectrophotometer (6-mm aperture, D-65 light source) was calibrated with black and white tiles and was operated in a 2^{o}C cooler environment.

Of the carcasses eventually selected for the study, 252 (56%) were produced by heifers and 198 (44%) were produced by steers. Cattle type, carcass weight, and yield grade were allowed to vary

randomly in the experimental sample. Carcasses with quality or dressing defects (i.e., blood splash, dark cutters, fat pulls, excessive trimming, etc.) were excluded from the study.

Longissimus Muscle Sampling and Postmortem Aging

After completion of carcass data collection, LM samples (4 cm thick) were removed from the 13th rib region of the left and right side of each carcass to be used for shear force measurement and sensory evaluation. Samples were packaged in barrier bags and transported in ice-filled coolers to the Colorado State University Meat Laboratory. Upon arrival, all samples were individually vacuum-packaged and aged at 2^{o}C until the 14th d postmortem. On the 14th d postmortem, vacuum-packaged LM samples were frozen and stored at -20^{o}C. All frozen LM sections subsequently were fabricated using a band saw (Model 400, AEW-Thurne, AEW Engineering Co. Ltd., Norwich, UK) to yield 1 steak (2.5 cm thick) per section. The LM steak from the right side of each carcass was designated for shear force measurements and the LM steak from the left side of each carcass was used for sensory analysis. The remaining portion of each LM section was stored at -20^{o}C for later analysis to determine total collagen and percent heat soluble collagen.

Shear Force Measurements

Steaks to be measured for shear force were stratified by marbling degree and maturity and randomly allocated to 3 blocks with 150 steaks per block. Blocks included equal numbers of steaks representing the 2 maturity levels and the 3 degrees of marbling within maturity level. Blocks were measured on 3 different days with steaks comprising an entire block being measured for shear force on the same day.

Frozen steaks used for Warner-Bratzler shear force (WBSF) and slice shear force (SSF) were tempered for 36 to 48 h to ensure that raw internal steak temperatures were between 1 and

5°C. Steaks then were cooked on a convection conveyor oven (Model 1832-EL XTL OVENS, BOFC Inc., Wichita, KS) to attain a peak internal temperature of 71°C. A type K thermocouple thermometer (AccuTuff 340, model 34040, Cooper-Atkins Corporation, Middlefield, CT), placed in the geometric center of each steak, was used to measure peak internal temperature.

Warner-Bratzler shear force and SSF measurements were obtained from the same steak using procedures described by Lorenzen et al., (2010). Within 5 min of recording peak internal temperature, a 1-cm-thick, 5-cm-long slice was removed from the steak parallel to the muscle fibers and sheared perpendicular to the muscle fibers, using a universal testing machine (Instron Corp., Canton, MA) equipped with a flat, blunt-end blade (crosshead speed: 500 mm/min, load capacity: 100 kg), resulting in a single SSF measurement for each steak. The lateral portion (~1/3) of the LM steak was used for SSF measurement. The remaining portion of each steak was allowed to equilibrate to room temperature (22°C) and 4 to 6 cores (1.2 cm in diam.) were removed from each steak parallel to the muscle fibers. Each core was sheared once, perpendicular to the muscle fibers, using a universal testing machine (Instron Corp., Canton, MA) fitted with a Warner-Bratzler shear head (crosshead speed: 200 mm/min, load cell capacity: 100 kg). Peak shear force of each core was recorded, and the resulting values were averaged to obtain a single WBSF for each steak.

Sensory Analysis

Cooked LM samples from the left side of each carcass were used for sensory analysis to characterize descriptive sensory attributes. Steaks designated for sensory analysis were stratified by maturity level and degree of marbling within maturity level and randomly allocated to 37 complete blocks (12 steaks per block) and 1 partial block (6 steaks). Each block consisted of equal numbers of steaks representing the 2 maturity levels and the 3 degrees of marbling within

maturity level. Two blocks were evaluated for sensory attributes on the same day (12 samples per session) with 5 h between sessions.

Panelists were trained, selected, and tested to determine their abilities to distinguish and rate differences in meat tenderness, juiciness, and flavor according to the procedures outlined by Adhikari and Miller (2010) and Miller and Prusa (2010). The lexicon of descriptive attributes used for sensory training and analysis (AMSA, 1995; Adhkari and Miller, 2010) included tenderness, juiciness, and the following flavor descriptors: meaty/brothy (basic flavor and aroma of grilled or roasted beef; simulated by the flavor of beef broth) buttery/beef fat (flavor and aroma associated with cooked fat from grain-finished beef; often described as a buttery flavor), bloody/ serumy (flavor and aroma associated with blood in beef cooked to a rare degree of doneness; sometimes described as a metallic taste), livery/organy (flavor and aroma associated with cooked beef liver or kidney), grassy (flavor and aroma of beef produced by grass-finished or short-fed cattle; often described as green or hay like), and gamey (flavor and aroma associated with game meat).

Frozen steaks used for each panel session were tempered for 36 to 48 h to ensure that raw internal steak temperatures were between 1 and 5^{o}C. Steaks were cooked on electric grills (model GGR64, Salton, Inc., Mt. Prospect, IL) that heated the steaks from both sides simultaneously to a target peak internal temperature of 71^{o}C. A type K thermocouple thermometer (AccuTuff 340, model 34040, Cooper-Atkins Corporation, Middlefield, CT) placed in the geometric center of each steak was used to measure peak internal temperature. After cooking, steaks were cut into 1.3 cm x 1.3 cm x 1.3 cm cubes, placed in a glass bowl, wrapped in aluminum foil, and held in a warming oven at 70^{o}C for a maximum of 30 min before being served to a 8-member trained descriptive attribute panel. Each panelist received 2 cubes from

each steak. To prevent bias, panelists were seated in individual cubicles equipped with red incandescent light to eliminate color differences among samples. Each panelist was supplied with unsalted saltine crackers, distilled water, and unsweetened apple juice for palate cleansing between samples. Sensory attributes of each sample were quantified using 15-cm unstructured line scales anchored at both ends with descriptive terms. For each line scale, 0 denoted a very low intensity of that specific attribute, while 15 denoted a very high intensity of the attribute. Sensory testing was conducted for 19 d with a 1-d retraining session conducted at mid-point. For each sample, individual panelists' scores were averaged to determine a single value for each sensory attribute.

Collagen Analysis

Collagen analysis was conducted on LM samples from the left carcass side, except for 5 cases in which the LM sample originated from the right carcass side. For these 5 carcasses an adequate amount of LM tissue could not be obtained from the left side. Each sample was individually homogenized until a fine powder-like consistency was obtained. At this time samples were composited so that a total of 45 samples from each maturity group were analyzed. Samples were sorted by quality grade and then overall maturity within quality grade. Within each maturity group, there were 15 samples from each marbling category. Five g of each individual sample was combined and thoroughly mixed to provide one composite that was used for collagen analysis. Heat soluble (HS) collagen was extracted from 4-g powdered, raw meat samples by heating the samples for 63 min at 77^{o}C in 12 mL of deionized water. Samples were then centrifuged at 4000 x g for 20 min at 4^{o}C to separate supernatant from the residue portion. After centrifugation and removal of the supernatant, the residue was re-suspended in 8 mL of distilled water and centrifugation was performed again. The volume of the supernatant was

recorded and the supernatant was stored at -20^{o}C until acid hydrolysis. The residue portion was placed in a drying oven at 103 ± 5^{o}C for 16 h and then stored at -20^{o}C. Each fraction (3 mL of HS or entire IS pellet) was combined with sarcosine (50000 pmol/µL; 0.1 mL for HS or 0.3 mL for IS) and HCl (3.1 mL of 12 N for HS or 0.3 mL of 12 N and 5.0 mL of 6 N for IS), flushed with nitrogen for 15 s, and heated for 16 h at 110^{o}C. Sarcosine served as the internal standard for the analysis of hydroxyproline

After hydrolysis, hydrolysate (0.50 mL of HS or 0.05 mL of IS) was neutralized by 6 N NaOH (0.5 mL for HS and 0.05 mL for IS) and diluted to total of 10 mL by HPLC water. An aliquot of 0.5 mL filtered through a Mini-UniPrep™ syringeless filter device with polytetrafluoroethylene membrane and polypropylene housing (Whatman, Cardiff, Wales, UK). A modified 2-step automatic pre-column derivatization process (Henderson et al., 2000) was employed to derivatize the primary amino acids with o-phthalaldehyde (OPA)/3-mercaptopropionic acid (3-MPA) and secondary amino acids with 9-fluorenylmethyl chloroformate, consecutively (FMOC, Agilent Technologies Inc., Santa Clara, CA). Amino acid derivatives were separated on a 150 mm × 4.6 mm Zorbax Eclipse C18 column (5 µm particle size) by a reversed-phase high-pressure liquid chromatography system (Shimadzu Scientific Instrument, Kyoto, Japan) with fluorescence detection at 266-nm excitation and 365-nm emission (specific secondary amino acids, i.e. hydroxyproline, sarcosine, and proline) Calculation was based on external standard calibration with internal standard correction.

Collagen content (HS or IS, mg/g) was calculated by multiplying the hydroxyproline concentration in sample (mg/g) with a factor of 7.52 or 7.25 for HS or IS, respectively (Cross et al., 1972). Percentage of heat soluble collagen was calculated by dividing heat soluble collagen by total collagen (soluble plus insoluble).

Statistical Methods

Exploratory data analyses were conducted using the FREQ, GLIMMX, and CORR procedures of SAS (SAS Inst. Inc., Cary, NC) to characterize the experimental sample and to determine relationships between overall maturity and instrument marbling score with sensory panel attributes and LM shear force measurements. Data for carcass characteristics, such as marbling score, fat thickness at the 12^{th} rib, REA, HCW, and calculated YG, were analyzed (PROC MIXED) to compare carcasses selected for each maturity group and marbling category. The statistical model included random effects of pair within marbling category and sex and collection day and fixed effects of maturity group and marbling category. Sensory panel ratings and LM shear force measures were analyzed using the MIXED procedure. The original statistical model included the random effects of pair within marbling category and sex, block, and collection day. Fixed effects for the original model included marbling category, sex, maturity group, and their respective two-way and three-way interactions. Two-way and three way-interactions were determined to not be significant ($P > 0.05$) and were removed from the statistical model. The final, reduced model included the random effects of pair within marbling category and sex, block, and collection day. The fixed effects for the reduced model included maturity group, marbling category, and maturity group x marbling category. The peak temperature of the steak after it was removed from the grill was used as a covariate. Denominator degrees of freedom were calculated using the Satterthwaite approximation. Collagen data were analyzed using the MIXED procedure. The statistical model included the fixed effects of maturity group and marbling category. All comparisons were tested using a comparison-wise significance level of $\alpha = 0.05$. In analyses conducted using MIXED and

GLIMMIX, least squares means were compared, using the PDIFF option of LSMEANS, when F-tests were significant ($P < 0.05$).

RESULTS AND DISCUSSION

Characteristics of Experimental Sample

The number of steer and heifer carcasses in each maturity group x marbling category is presented in Table 6.1. Overall 56% of the samples originated from heifer carcasses and 44% originated from steer carcasses. The sampling criteria required B-C maturity carcasses be paired with A maturity carcasses of the same sex and similar marbling score, resulting in the proportion of heifers and steers selected for each maturity level did not differ. There was a trend ($P = 0.1057$) for an increased proportion of heifers to be selected as marbling degree increased. This trend is indicative of the tendency for heifers to have a higher marbling score than steers when compared at a similar marketing endpoint (Grona et al., 2002; Anderson and Gleghorn, 2007). In addition, heifer carcasses had increased ($P < 0.05$) subcutaneous fat thickness over the LM at the 12^{th} rib and decreased ($P < 0.05$) LM area and HCW. While sex impacted some carcass characteristics, sex did not influence ($P > 0.05$) sensory attributes or shear force measurements.

Data characterizing USDA Quality Grade traits and LM color scores for each maturity group and marbling category are presented in Table 6.2. Sampling criteria required that all selected A maturity carcasses were within 30 marbling degrees of its paired B-C carcass. As a result marbling score did not differ ($P > 0.05$) between maturity groups. Due to study design, skeletal, lean, and overall maturity scores were greater ($P < 0.05$) in B-C maturity carcasses than in A maturity carcasses. Overall maturity scores ranged from A^{30} to A^{90} within the A maturity group and B^{00} to C^{90} within the B-C maturity group. In addition, LM color score measurements reflected the increased lean and overall maturity scores. L* and a* values differed ($P < 0.05$) for

maturity group. B* values were similar ($P > 0.05$) for LM steaks from A or B-C maturity carcasses. LM steaks from B-C maturity carcasses had lower ($P < 0.05$) L* values (darker) and higher ($P < 0.05$) a* values (redder) than LM steaks from A maturity carcasses. These color differences suggest that LM steaks from B-C maturity carcasses were darker and less cherry-red. It is generally recognized that as an animal advances in age the muscle tissue becomes darker red in color. Tuma et al. (1963), Romans et al. (1965), and Breidenstein et al. (1968) also noted a darker lean tissue color in carcasses with advanced skeletal maturity characteristics.

An increased degree of marbling was generally associated with increased ($P < 0.05$) subcutaneous fat thickness at the 12^{th} rib, decreased ($P < 0.05$) LM area, and increased ($P < 0.05$) calculated yield grade. Least squares means for HCW were similar ($P > 0.05$) for carcasses in all three marbling categories. The lean color measurements, a* and b*, differed ($P < 0.05$) for marbling category. L* values were not affected ($P > 0.05$) by marbling category. Carcasses from the MT+ marbling category had higher ($P < 0.05$) a* and b* values as compared to LM steaks from SL and SM carcasses.

Effects of Maturity Group and Marbling Classification on Sensory Attributes and Shear Force Measurements

Results of studies conducted over the past several decades to determine the effect of maturity on sensory panel attributes of beef samples from grain-finished steers and heifers have returned inconsistent results (Miller et al., 1983; Field et al., 1997). Results from least squares means analysis showing the effects of maturity group, marbling category, and their respective interaction on sensory attributes and shear force measurements are summarized in Tables 6.3 and 6.4. Maturity group had no effect ($P > 0.05$) on any of the sensory characteristics or shear force measurements described in Tables 6.3 and 6.4. In addition, the percent of steaks from each

maturity group that would meet the ASTM specifications for "Certified Tender" did not differ ($P > 0.05$) for WBSF or SSF measurements (Table 6.4). Similar to the present study, other researchers have reported that sensory panel tenderness values do not differ in LM steaks from A or B maturity carcasses (Romans et al., 1965; Covington et al., 1970; Norris et al., 1971; Field et al., 1997; Hilton et al., 1998). Some studies have reported that LM steak sensory tenderness values do not differ between A and C maturity carcasses (Cross et al., 1973; Regan et al., 1976; Field et al., 1997). In contrast, Smith et al. (1982 and 1988) reported that LM steaks from A and B maturity carcasses differed in sensory tenderness and WBSF values.

Previous studies have shown that sensory tenderness and Warner-Bratzler shear force values improve when cattle are finished on grain regardless of age (Tatum et al., 1980; Aberle et al., 1981; Miller et al., 1987; Schnell et al., 1997). In grain-finished steers and heifers, protein turnover occurs at rapid rate limiting the formation of heat-stable collagen crosslinks that lead to tough beef. In addition, endogenous and exogenous hormone levels may cause premature skeletal ossification causing a carcass to appear more mature than its true chronological age (Waggoner et al., 1990; Apple et al., 1991; Field et al., 1996). Shackelford et al. (1995) determined that heiferettes (mean age = 35.9 months; mean skeletal maturity score = B^{78}) finished on grain had similar overall sensory tenderness ratings as yearling heifers (mean age = 22.2 months; mean skeletal maturity score = A^{80}). The rapid protein turnover of collagen in grain-finished animals classified as less than 30 MOA by dentition may prevent heat stable collagen crosslinks from forming allowing the beef produced from these animals to remain tender regardless of USDA maturity classification.

Previous research has indicated that sensory juiciness and flavor values are not affected by maturity when only comparing A and B maturity carcasses (Smith et al., 1982; Hilton et al.,

1998). Flavor intensity may decrease and off-flavor intensity has been reported to increase in C maturity carcasses as compared to A maturity carcasses (Smith et al., 1982; Hilton et al., 1998). An interaction between maturity group and marbling classification was present ($P < 0.05$) for bloody/serumy flavor intensity. However, bloody/serumy flavor intensity was detected at average levels below 2 cm on a 15 cm line scale and would likely not impact the overall sensory experience. In the present study, livery/organy, grassy, and gamey flavors were detected at extremely low levels (mean values < 1 cm on a 15 cm scale). Similarly, Emerson et al. (2013) reported in grain-finished cattle that livery/organy and grassy flavors were detected at levels below 1 cm on a 15 cm scale.

Pearson correlation coefficients quantifying linear associations among overall maturity and instrument marbling score with various beef sensory attributes and LM shear force measurements are presented in Table B.3. Overall maturity score was very weakly associated with grassy flavor intensity ($r = 0.11$) and gamey flavor intensity ($r = 0.13$). This suggests that overall maturity explains less than 2% of the variation in grassy and gamey flavor intensity. However as previously mentioned very small amounts (<1 cm on a 15 cm scale) of grassy and gamey flavors were detected in the experimental sample. In this study, overall maturity did not prove to be a good predictor of any of the sensory attributes or shear force values. Conversely, Smith et al. (1988) reported that overall maturity was associated with sensory tenderness, flavor, juiciness, overall palatability, and WBSF measurements.

While differences were not detected due to maturity group, marbling category had a significant effect ($P < 0.05$) on sensory tenderness, juiciness, meaty/brothy flavor intensity, buttery/beef fat flavor intensity, bloody/serumy flavor intensity and livery/organy flavor intensity (Table 6.3). As marbling category increased from SL to MT+, LM steaks had increased ($P <$

0.001) tenderness, juiciness, meaty/brothy flavor intensity, and buttery/beef fat flavor intensity. Bloody/serumy flavor intensity and livery/organy flavor intensity decreased ($P < 0.05$) as marbling degree increased. Previously, Emerson et al. (2013), McBee and Wiles (1967), and Smith et al. (1984) have reported similar relationships between marbling category and beef sensory properties in LM steaks. Hiner (1956) and McBee and Wiles (1967) stated that flavor increased in a direct, linear relationship with additional degrees of marbling. Research has suggested that overall sensory ratings improve as marbling degree increase (Smith et al., 1984; Emerson et al., 2013) thus providing a steak with a better eating experience.

Shear force measurements were affected ($P < 0.05$) by marbling category (Table 6.4). A higher marbling category resulted in decreased WBSF values (SL > SM > MT+) and decreased SSF values (SL > SM = MT+). Emerson et al. (2013) reported that WBSF values decreased with increased degree of marbling from Traces (TR) to Moderately Abundant. In addition, Emerson et al. (2013) determined that SSF values decreased from TR to SM but an additional increase in marbling degree above SM did not further reduce SSF values.

Effects of Maturity Group and Marbling Category on Collagen Analysis

As animal ages, the concentration of mature, thermally stable cross-links increase (Smith and Judge, 1991). These more mature collagen crosslinks can lead to a decrease in tenderness and overall palatability. However, research has shown that animals finished on a high energy diet do not experience the formation of mature collagen crosslinks. When animals are grain-finished on a high-energy diet, periods of rapid growth and protein turnover occur causing new, heat soluble collagen crosslinks to be synthesized (Aberle et al., 1981; Wu et al., 1981; Miller et al., 1987). Cattle on a high energy diet prior to slaughter will produce tender meat as a result off the high-proportion of heat soluble collagen, regardless of age or skeletal maturity.

Results from least squares analyses showing the effects of marbling category and maturity group on total collagen and percent heat soluble collage are summarized in Table 6. 5. Total collagen amount did not differ $P > 0.05$) among marbling categories or between maturity groups. However, maturity group and marbling category interacted ($P < 0.05$) to affect collagen amount. Total collagen content was highest for B-C maturity carcasses in the MT+ category and lowest for A maturity carcasses in the MT+ category. As a result, total collagen content differed ($P < 0.05$) between maturity groups within the MT+ category. In several other studies, total collagen amount has been shown to not differ in animals over 12 months of age, regardless of maturity classification or finishing diet (Miller et al., 1987; Cranwell et al., 1996; Field et al., 1997; Schnell et al., 1997).

Percent heat soluble collagen was higher ($P < 0.05$) in LM steaks from B-C maturity carcasses. Contrary to this study, Field et al. (1997) and Miller et al. (1983) reported that percent heat soluble collagen did not vary between maturity groups. While there were differences in percent heat soluble collagen due to maturity group these differences likely did not have much practical meaning since tenderness differences were not found among the samples. Heat soluble collagen content was effected ($P < 0.05$) by marbling category. Steaks produced from carcasses with a SM degree of marbling had more ($P < 0.05$) heat soluble collagen than steaks produced from carcasses with a SL degree of marbling.

Implications

During the aging process, ossification of cartilage will occur and lean tissue will become darker in color and coarser in texture. The current Official Standards for Grades of Carcass Beef (USDA, 1997) utilize a combination of sex classification, lean and skeletal maturity, marbling score, and firmness of the *Longissimus dorsi* muscle to assign an USDA Quality Grade. Skeletal

characteristics such as size, shape, and ossification of bones and cartilage, as well as, the color and texture of the lean are supposed to serve as indicators of an animal's chronological age. The current standards for A through E overall maturity correspond with the following ages: A = 9 to 30 mo, B = 30 to 42 mo, C = 42 to 72 mo, D = 72 to 96 mo, and E = more than 96 mo.

In addition, the current Quality Grade Standards require an increased marbling score after A maturity to compensate for tenderness and overall palatability differences that may occur due to increased age. These standards exclude B maturity carcasses from the Select grade and carcasses with less than Modest^{00} are graded as Standard. As a result, the price received for these cattle is substantially decreased due to discounts (USDA, 2013). Previous research has indicated that as animal age increases, overall tenderness decreases (Smith et al., 1982 and 1988; Hilton et al., 1998). The grading of B-maturity carcasses with SM or SL marbling scores are based off of research conducted by Smith et al. (1982 and 1988). Smith et al. (1982) reported that beef produced from carcasses within A maturity were less variable in terms of overall palatability. Within the A maturity group, difference in flavor, juiciness, tenderness, overall palatability, and WBSF did not exist, however, starting in the B maturity group tenderness and overall palatability differences did exist (Smith et al., 1988).

However, research has shown that skeletal maturity scores may increase at a rate faster than the increase in chronological age. This is most prevalent in cattle with increased levels of endogenous or exogenous estrogen levels such as heifers, heiferettes, and/or cattle that receive implants. Estrogen is known to be a potent activator of skeletal ossification causing females or cattle that receive implants to exhibit advance skeletal characteristics than their male or non-implanted counterparts (Turner et al., 1981; Foutz et al., 1997; Paisley et al., 1999; Roeber et al., 2000; Reiling and Johnson, 2003; Tatum et al., 2011). Tatum (2011) reported that after 18 MOA

the odds of an animal producing a B maturity carcass dramatically increased especially in heifers where females were seven times more likely to produce a B maturity carcass and eleven times more likely to produce a C maturity carcass than their male counterparts. Other reserachers reported the use of estrogen-containing implants lead to an increase in skeletal maturity and thus overall maturity (Turner et al., 1981; Foutz et al., 1997; Paisley et al., 1999; Roeber et al., 2000; Reiling and Johnson, 2003). These studies suggest that skeletal and overall maturity may not always be indicative of chronological age since endogenous or exogenous estrogen levels can increase the rate of skeletal ossification prematurely.

In the United States most (92.8%) beef carcasses produced by fed steers and heifers are classified as A maturity, however, a small percentage will produce B maturity or older carcasses even when the animal is under 30 MOA (Moore et al., 2012). The results of the current study combined with previous tenderness research in grain-finished cattle indicate that when cattle classified as less than 30 MOA by dentition are grained finished that sensory characterisitcs do not differ, regardless of skeletal and overall maturity. As a result, the current price disount B maturity carcasses receive is unjustified. A potential change in the Quality Grade standards to remove maturity requirements in cattle classified as less than 30 MOA by dentition would make a large, positive economic impact on the U.S. beef cattle industry. In addition to eliminating an unnecessary price discount eliminating the increased marbling score requirement would incrase the supply of carcasses that quality for the Choice and Select grades. Removing maturity from the Quality Grade standards for grain-finished cattle classified as less than 30 MOA by dentition may allow an increase in the use of instrument grading and a decrease in the dependence on human graders to determine overall maturity. Based on the data presented in the current study, price disounts for B maturity carcasses orginating from cattle classified as less than 30 months of

age based on dentition are unjustified. These results suggest that in grain-finished cattle the grading concept of using skeletal maturity characteristics to reflect differences in collagen maturity and associated tenderness differences does not apply. Current grading practices may need to be modified to reflect these findings which can help increase the value of the U.S. beef supply.

Table 6.1. Sample of steer and heifer carcasses (n = 450) selected to represent 2 maturity groups and 3 marbling categories

	A maturity[1]		B-C maturity[2]	
Marbling category	Steer	Heifer	Steer	Heifer
	Number of carcasses			
Slight	38	37	38	37
Small	32	43	32	43
Modest+[3]	29	46	29	46

[1] A = carcasses exhibiting A^{00} to A^{99} overall maturity characteristics.
[2] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity characteristics.
[3] Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.

Table 6.2. USDA quality grade traits and objective LM color measurements for beef carcasses to represent 2 maturity groups and 3 marbling categories

		USDA quality grade trait[1]				LM color measurement[2]		
Effect	*N*	Marbling score	Skeletal maturity score	Lean maturity score	Overall Maturity Score	L*	a*	b*
Maturity (MAT)		*P* = 0.6217	*P* < 0.0001	*P* < 0.0001	*P* < 0.0001	*P* = 0.0156	*P* = 0.0271	*P* = 0.3689
A[3]	225	456	160	149	155	39.6[a]	12.1[b]	25.5
B-C[4]	225	458	281	160	241	38.8[b]	12.4[a]	25.2
SEM		4.4	3.1	2.0	2.7	0.84	0.27	0.48
Marbling (MARB)		*P* < 0.0001	*P* = 0.6079	*P* = 0.5692	*P* = 0.8929	*P* = 0.1214	*P* = 0.0060	*P* = 0.0223
Slight	150	362[c]	220	155	198	38.7	11.7[b]	24.6[b]
Small	150	442[b]	219	156	197	39.2	12.2[b]	25.2[b]
Modest+[5]	150	569[a]	223	153	199	39.8	12.9[a]	26.3[a]
SEM		5.0	3.6	2.8	3.2	0.86	0.33	0.58
MAT X MARB		*P* = 0.8834	*P* = 0.6851	*P* = 0.5883	*P* = 0.8575	*P* = 0.6205	*P* = 0.5350	*P* = 0.7742
A Slight	75	362	158	148	154	39.1	11.5	24.7
A Small	75	439	160	150	155	39.3	12.1	25.4
A Modest+	75	568	162	148	157	40.3	12.7	26.3
B-C Slight	75	361	282	161	242	38.2	11.9	24.4
B-C Small	75	444	277	162	239	39.0	12.2	25.0
B-C Modest+	75	570	283	157	241	39.3	13.2	26.3
SEM		6.0	4.6	3.2	4.1	0.90	0.38	0.63

[1] Marbling scores were measured using USDA-approved, grading instruments (Slight = 300, Small = 400 to 499, Modest = 500 to 599); carcass maturity characteristics (USDA, 1997) were evaluated and scored by official USDA graders (A = 100 to 199, B = 200 to 299).
[2] L*: 0 = black, 100 = white; a*: negative number = green, positive number = red; b*: negative number = blue, positive number = yellow.
[3] A = carcasses exhibiting A^{00} to A^{99} overall maturity characteristics.
[4] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity characteristics.
[5] Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.
[a-c] Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

Table 6.3. Least squares means comparing sensory attributes of LM steaks from carcasses representing 2 maturity groups and 3 marbling categories

Effect	*N*	LM sensory attribute[1]							
		Tenderness	Juiciness	Meaty/ brothy flavor	Buttery/ beef fat flavor	Bloody/ serumy flavor	Livery/ organy flavor	Grassy flavor	Gamey flavor
Maturity (MAT)		*P* = 0.5301	*P* = 0.8490	*P* = 0.4499	*P* = 0.6446	*P* = 0.1270	*P* = 0.5903	*P* = 0.0743	*P* = 0.9347
A[1]	225	8.14	7.51	8.01	5.73	1.22	0.32	0.16	0.07
B-C[2]	225	8.05	7.52	8.06	5.77	1.12	0.34	0.22	0.07
SEM		0.157	0.068	0.072	0.095	0.096	0.038	0.027	0.016
Marbling (MARB)		*P* < 0.001	*P* < 0.001	*P* < 0.001	*P* < 0.001	*P* = 0.0079	*P* < 0.001	*P* = 0.0744	*P* = 0.2878
Slight	150	7.35^{c}	7.01^{c}	7.52^{c}	4.97^{c}	1.41^{a}	0.43^{a}	0.24	0.09
Small	150	8.08^{b}	7.45^{b}	8.07^{b}	5.67^{b}	1.18^{b}	0.35^{a}	0.19	0.08
Modest+[4]	150	8.85^{a}	8.09^{a}	8.51^{a}	6.62^{a}	0.92^{c}	0.22^{b}	0.14	0.05
SEM		0.175	0.076	0.080	0.107	0.103	0.045	0.032	0.023
MAT X MARB		*P* = 0.2718	*P* = 0.5874	*P* = 0.3737	*P* = 0.9574	*P* = 0.0276	*P* = 0.3170	*P* = 0.8475	*P* = 0.1512
A Slight	75	7.26	6.96	7.50	4.96	1.59^{a}	0.39	0.22	0.09
A Small	75	8.13	7.49	7.99	5.66	1.18^{bc}	0.38	0.16	0.10
A Modest+	75	9.02	8.09	8.54	6.58	0.89^{d}	0.19	0.11	0.03
B-C Slight	75	7.43	7.07	7.53	4.98	1.23^{b}	0.48	0.25	0.10
B-C Small	75	8.04	7.41	8.16	5.69	1.18^{bc}	0.31	0.23	0.06
B-C Modest+	75	8.68	8.09	8.49	6.65	0.95^{cd}	0.24	0.18	0.07
SEM		0.207	0.097	0.099	0.128	0.118	0.058	0.043	0.028

[1] Scored using 15-cm unstructured line scales: 0=extremely dry, extremely tough, no presence of flavor, or minimal level of performance; 15=extremely juicing, extremely tender, strong presence of flavor, or maximal level of performance.
[2] A = carcasses exhibiting A^{00} to A^{99} overall maturity characteristics.
[3] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity characteristics.
[4] Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.
[a-c] Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

Table 6.4. Least squares means comparing Warner-Bratzler shear force (WBSF) and slice shear force (SSF) measurements of LM steaks from carcasses representing 2 maturity groups and 3 marbling categories

		LM shear force measurement, kg		Steaks meeting ASTM specifications for "Certified Tender[1]," %	
Effect	*N*	WBSF	SSF	WBSF specification	SSF specification
Maturity (MAT)		*P* = 0.5915	*P* = 0.1139	*P* = 0.6712	*P* = 0.2356
A[1]	225	4.18	18.05	66.4	74.6
B-C[2]	225	4.14	18.68	64.2	69.3
SEM		0.082	0.369	4.79	5.21
Marbling (MARB)		*P* < 0.0001	*P* = 0.0018	*P* < 0.0001	*P* = 0.0003
Slight	150	4.55[a]	20.03[a]	42.1[c]	57.4[b]
Small	150	4.17[b]	17.72[b]	65.2[b]	75.5[a]
Modest+[4]	150	3.75[c]	17.35[b]	83.1[a]	80.4[a]
SEM		0.095	0.464	5.45	6.37
MAT X MARB		*P* = 0.2718	*P* = 0.5874	*P* = 0.9574	*P* = 0.0276
A Slight	75	4.63	19.91	42.6	59.6
A Small	75	4.14	17.82	62.6	73.3
A Modest+	75	3.76	16.41	86.1	86.2
B-C Slight	75	4.47	20.15	41.5	55.1
B-C Small	75	4.19	17.61	67.6	77.6
B-C Modest+	75	3.75	18.28	79.6	72.9
SEM		0.112	0.579	6.87	7.65

[1] Minimum tenderness threshold values (MTTV) required for classification as "Certified Tender": WBSF = 4.4 kg, SSF = 20 kg (ASTM International, 2011).
[2] A = carcasses exhibiting A^{00} to A^{99} overall maturity characteristics.
[3] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity characteristics.
[4] Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.
[a-c] Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

Table 6.5. Least squares means comparing collagen content of LM samples from carcasses representing 2 maturity groups and 3 marbling categories

Effect	*N*	Total collagen content, mg/g	Heat soluble collagen, %
Maturity (MAT)		*P* = 0.1486	*P* = 0.0020
A[1]	225	4.44	15.86[b]
B-C[2]	225	4.77	17.63[a]
SEM		0.161	0.395
Marbling (MARB)		*P* = 0.6753	*P* = 0.0179
Slight	150	4.74	15.71[bc]
Small	150	4.49	17.71[a]
Modest+[4]	150	4.59	16.8[ab]
SEM		0.199	0.488
MAT X MARB		*P* = 0.0046	*P* = 0.54221
A Slight	75	5.04[ab]	15.13
A Small	75	4.43[bc]	19.94
A Modest+	75	4.32[bc]	15.49
B-C Slight	75	4.66[bc]	16.30
B-C Small	75	3.96[c]	18.49
B-C Modest+	75	5.23[a]	18.11
SEM		0.282	0.690

[1] A = carcasses exhibiting A^{00} to A^{99} overall maturity characteristics.
[2] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity characteristics.
[3] Modest+ = carcasses with $Modest^{00}$ or greater marbling scores.
[a-c] Means in the same column within an effect that do not share a common superscript letter differ ($P < 0.05$).

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APPENDIX A

Table A.1. Pre-determined sampling matrix for quality grade, yield grade, gender, and genetics for each university and plant.

University[1]	Plant	Animal #	Quality Grade[2]	Yield Grade	Gender[3]	Genetics[4]
TAMU	Greenbay	1	U	2	S	D
TAMU	Greenbay	2	U	3	S	N
TAMU	Greenbay	3	L	2	H	N
TAMU	Greenbay	4	L	3	S	D
TAMU	Greenbay	5	S	2	S	N
CSU	Greeley	6	U	2	S	N
CSU	Greeley	7	U	3	S	N
CSU	Greeley	8	L	2	S	N
CSU	Greeley	9	L	3	H	N
CSU	Greeley	10	S	2	H	N
CSU	Greeley	11	S	3	S	N
CSU	Dodge City	12	U	2	H	N
CSU	Dodge City	13	U	3	H	N
CSU	Dodge City	14	L	2	S	N
CSU	Dodge City	15	L	3	S	N
CSU	Dodge City	16	S	2	S	N
CSU	Dodge City	17	S	3	H	N
CSU	Dodge City	18	S	3	S	N
TAMU	Corpus Christi	19	U	3	S	N
TAMU	Tolleson	20	L	2	S	D
TAMU	Corpus Christi	21	L	3	S	N
TAMU	Corpus Christi	22	S	2	H	N
TAMU	Tolleson	23	S	3	S	D
TTU	Plainview	24	U	3	H	N
TTU	Plainview	25	U	2	S	N
TTU	Plainview	26	L	2	H	N
TTU	Plainview	27	L	3	S	N
TTU	Plainview	28	S	2	S	N
TTU	Plainview	29	S	3	S	N
TTU	Omaha	30	U	2	S	N
TTU	Omaha	31	U	2	H	N
TTU	Omaha	32	U	3	S	N
TTU	Omaha	33	L	2	S	N
TTU	Omaha	34	L	3	H	N
TTU	Omaha	35	S	2	S	N
TTU	Omaha	36	S	3	H	N

[1] TAMU=Texas A&M University; CSU=Colorado State University; TTU=Texas Tech University.

[2] U=Upper Two-Thirds Choice (Modest^{00} to Moderate^{99}); L= Low Choice (Small^{00} to Small^{99}); S= Select (Slight^{00} to Slight^{99}).

[3] H=Heifer; S=Steer.

[4] D=Dairy type; N=Non-dairy type.

Table A.2. Beef loin and round cuts to be collected, dissected, and analyzed for Phase 3

Cut	Trim Level, cm	URMIS[1]	IMPS[2]	Cook Method[3]
Beef, Short Loin, Porterhouse Steak	0.32	1330/2145	1173	Grilled
Beef, Short Loin, T-Bone Steak	0.32	1369/2184	1174	Grilled
Beef, Loin, Top Loin Steak, Boneless	0 or 0.32	1404/2219	1180	Grilled
Beef, Loin, Tenderloin Roast	0	1386/2201	190A	Roasted
Beef, Loin, Tenderloin Steak	0	1388/2203	1190A	Grilled
Beef, Round, Eye of Round Steak	0	1481/2296	1171	NA
Beef, Round, Eye of Round Roast	0	1480/2295	171C	NA
Beef, Round, Top Round Steak	0	1553/2368	1168	NA
Beef, Round, Top Round Roast	0	1551/2366	169	NA

[1] URMIS=Uniform meat retail identity standards

[2] IMPS=Institutional Meat Purchase Specifications

[3] NA= Non-Applicable

Table A.3. Least squares means for cooking[1] yield[2] for six retail beef loin cuts

Retail cut, trim level	Cook yield, %	SEM
Number of carcasses	36	
Porterhouse steak, 0.32 cm	87.1[a]	1.30
T-bone steak, 0.32 cm	87.6[a]	1.29
Tenderloin roast, 0 cm	82.0[d]	1.40
Tenderloin steak, 0 cm	78.4[e]	1.36
Top loin steak, 0 cm	84.8[c]	1.31
Top loin steak, 0.32 cm	85.7[b]	1.30

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[2] Cooking yield, %: (hot cooked weight/pre-cooking raw weight) x 100.

Table A.4. Raw and cooked least squares means ± SEM for percent moisture, fat, protein, and ash on U.S. beef loin and round retail cuts

	Proximate values			
Retail cut, trim level	Moisture, %	Fat, %	Protein, %	Ash, %
Number of carcasses	36	36	36	36
Raw loin cuts				
Porterhouse steak, 0.32 cm	70.3 ± 0.042^{c}	6.6 ± 0.047^{a}	22.3 ± 0.035^{b}	1.02 ± 0.041^{b}
T-bone steak, 0.32 cm	70.7 ± 0.042^{b}	6.5 ± 0.047^{a}	22.2 ± 0.035^{b}	1.01 ± 0.041^{b}
Top loin steak, 0 and 0.32 cm[1]	70.6 ± 0.042^{bc}	5.7 ± 0.047^{b}	23.1 ± 0.035^{a}	1.02 ± 0.041^{b}
Tenderloin roast/steak, 0 cm[2]	72.5 ± 0.042^{a}	5.7 ± 0.047^{b}	21.9 ± 0.035^{c}	1.11 ± 0.041^{a}
Raw loin cuts				
Eye of round roast/steak, 0 cm[3]	73.4 ± 0.50^{a}	3.1 ± 0.036	23.4 ± 0.030^{b}	1.10 ± 0.041
Top round roast/steak, 0 cm[4]	73.0 ± 0.50^{b}	2.9 ± 0.036	23.6 ± 0.030^{a}	1.12 ± 0.042
Cooked[5] *loin cuts*				
Porterhouse steak, 0.32 cm	61.1 ± 0.43^{b}	10.3 ± 0.076^{a}	28.2 ± 0.060^{c}	1.06 ± 0.036^{c}
T-bone steak, 0.32 cm	61.1 ± 0.43^{b}	10.4 ± 0.076^{a}	27.9 ± 0.060^{cd}	1.05 ± 0.036^{d}
Top loin steak, 0.32 cm	61.5 ± 0.43^{b}	9.2 ± 0.076^{b}	29.0 ± 0.060^{b}	1.15 ± 0.036^{c}
Top loin steak, 0 cm	61.8 ± 0.43^{b}	8.5 ± 0.076^{c}	29.5 ± 0.060^{b}	1.15 ± 0.036^{c}
Tenderloin roast, 0 cm	64.8 ± 0.43^{a}	7.5 ± 0.076^{d}	27.5 ± 0.060^{d}	1.24 ± 0.036^{b}
Tenderloin steak, 0 cm	60.8 ± 0.43^{b}	8.3 ± 0.076^{c}	30.8 ± 0.060^{a}	1.38 ± 0.036^{a}

[1] Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.
[2] Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak.
[3] Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak.
[4] Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-c] Within a column and raw/cooked and loin/round, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.5. Effects of USDA quality grade, USDA yield grade, and gender on the fat content (g/100g) of the separable lean from raw loin and round cuts and cooked loin cuts

	USDA Quality Grade					USDA Yield Grade				Gender			
Retail cut, trim level	Upper Choice	Low Choice	Select	SEM	*P*-value	YG 2	YG 3	SEM	*P*-value	Heifer	Steer	SEM	*P*-value
Number of carcasses	12	12	12	-		18	18	-		12	20	-	
Raw loin means[1]	7.7[a]	6.4[b]	5.1[c]	0.49	<0.001	5.9	6.3	0.45	0.100	6.2	6.0	0.47	0.479
Raw round means[2]	3.6	3.2	2.5	0.40	<0.001	2.6	3.1	0.37	0.462	3.1	2.9	0.38	0.269
Cooked[3] loin means[1]	11.1[a]	9.4[b]	7.7[c]	0.77	<0.001	8.6[b]	9.5[a]	0.75	0.009	9.3	8.7	0.77	0.109

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.6. Effects of USDA quality grade, USDA yield grade, and gender on the moisture content (g/100g) of the separable lean from raw loin and round cuts and cooked loin cuts

Retail cut, trim level	USDA Quality Grade					USDA Yield Grade				Gender			
	Upper Choice	Low Choice	Select	SEM	*P*-value	YG 2	YG 3	SEM	*P*-value	Heifer	Steer	SEM	*P*-value
Number of carcasses	12	12	12	-	-	18	18	-	-	12	20	-	-
Raw loin means[1]	69.7[c]	70.7[b]	72.0[a]	0.42	<0.001	71.2[a]	70.8[b]	0.41	0.065	70.9	71.1	0.42	0.385
Raw round means[2]	72.8[b]	73.0[b]	73.6[a]	0.51	0.012	73.3	73.1	0.50	0.509	73.0[b]	73.3[a]	0.51	0.265
Cooked[3] loin means[1]	60.5[c]	61.4[b]	63.0[a]	0.43	<0.001	62.2[a]	61.5[b]	0.38	0.020	61.6	62.0	0.42	0.219

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.7. Effects of USDA quality grade, USDA yield grade, and gender on the protein content (g/100g) of the separable lean from raw loin and round cuts and cooked loin cuts

	USDA Quality Grade					USDA Yield Grade				Gender			
Retail cut, trim level	Upper Choice	Low Choice	Select	SEM	*P*-value	YG 2	YG 3	SEM	*P*-value	Heifer	Steer	SEM	*P*-value
Number of carcasses	12	12	12	-	-	18	18	-	-	12	20	-	-
Raw loin means[1]	21.9[b]	22.4[ab]	22.6[a]	0.36	< 0.001	22.4	22.4	0.35	0.577	22.4	22.4	0.35	0.772
Raw round means[2]	23.5	23.5	23.5	0.30	0.963	23.5	23.5	0.30	0.539	23.4	23.5	0.31	0.161
Cooked[3] loin means[1]	28.0[b]	28.7[a]	29.3[b]	0.59	< 0.001	28.8	28.8	0.58	0.753	28.8	28.9	0.59	0.547

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.8. Effects of USDA quality grade, USDA yield grade, and gender on the ash content (g/100g) of the separable lean from raw loin and round cuts and cooked loin cuts

	USDA Quality Grade					USDA Yield Grade				Gender			
Retail cut, trim level	Upper Choice	Low Choice	Select	SEM	*P*-value	YG 2	YG 3	SEM	*P*-value	Heifer	Steer	SEM	*P*-value
Number of carcasses	12	12	12	-	-	18	18	-	-	12	20	-	-
Raw loin means[1]	1.03	1.03	1.05	0.042	0.303	1.04	1.04	0.041	0.922	1.04	1.04	0.041	0.878
Raw round means[2]	1.12	1.11	1.10	0.044	0.524	1.12	1.10	0.042	0.085	1.11	1.11	0.043	0.725
Cooked[3] loin means[1]	1.15	1.16	1.19	0.029	0.083	1.17	1.17	0.028	0.978	1.17	1.16	0.029	0.693

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

Table A.9. Effect of USDA quality grade on raw and cooked least squares means for separable components (%) of U.S. beef loin and round retail cuts

	Loin cuts[1], raw	Round cuts[2], raw	Loin cuts[1], cooked[3]
Separable lean[4], %			
Upper Choice	79.8	98.0	79.7
Low Choice	80.1	98.2	80.1
Select	80.1	98.1	79.4
SEM	0.57	0.39	0.35
P-value	0.861	0.800	0.323
Separable seam fat[5], %			
Upper Choice	2.9	0.05	2.3[a]
Low Choice	2.6	0.03	2.1[a]
Select	2.5	0.07	1.7[b]
SEM	0.26	0.029	0.19
P-value	0.396	0.191	0.007
Separable external fat[6], %			
Upper Choice	6.1	1.0	5.8[a]
Low Choice	5.9	0.9	5.7[a]
Select	5.7	0.9	5.0[b]
SEM	0.49	0.31	0.21
P-value	0.639	0.753	0.017
Separable refuse[7], %			
Upper Choice	19.6	1.5	19.8
Low Choice	19.3	1.4	19.4
Select	19.3	1.5	20.1
SEM	0.58	0.35	0.34
P-value	0.869	0.860	0.263

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

[4] Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.

[5] Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.

[6] External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.

[7] Refuse weight (g) includes all bone and heavy connective tissue, include the membrane covering external fat. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.

[a-c] Within a row and USDA Quality Grade/USDA Yield Grade/gender, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.10. Effect of gender on raw and cooked least squares means for separable components (%) of U.S. beef loin and round retail cuts

	Loin cuts[1], raw	Round cuts[2], raw	Loin cuts[1], cooked[3]
Separable lean[4], %			
Heifer	80.0	98.1	79.3
Steer	80.0	98.0	79.7
SEM	0.58	0.37	0.36
P-value	0.929	0.906	0.413
Separable seam fat[5], %			
Heifer	2.7	0.1	2.1
Steer	2.7	0.04	2.0
SEM	0.27	0.026	0.16
P-value	0.780	0.748	0.748
Separable external fat[6], %			
Heifer	6.1	0.9	6.0[a]
Steer	5.9	1.0	5.4[b]
SEM	0.49	0.31	0.37
P-value	0.489		0.024
Separable refuse[7], %			
Heifer	19.3	1.5	20.2
Steer	19.5	1.5	19.8
SEM	0.59	0.34	0.35
P-value	0.469	0.782	0.367

[1] Loin cuts included: porterhouse steak, t-bone steak, top loin steak (0 and 0.32 cm trim), and tenderloin roast/steak. Least squares means generated for raw, tenderloin roast were used to represent values for raw, tenderloin steak. Least squares means generated for raw, top loin steak, 0.32 cm were used to represent values for raw, top loin steak, 0 cm trim.

[2] Round cuts included: eye of round roast/steak and top round roast/steak. Least squares means generated for raw, eye of round roast were used to represent values for raw, eye of round steak. Least squares means generated for raw, top round roast were used to represent values for raw, top round steak.

[3] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

[4] Separable lean weight (g) includes any intramuscular fat. Separable lean, %: [separable lean (g)/ pre-dissection cut weight (g)] x 100.

[5] Seam fat weight (g) includes any fat which lies between muscles. Seam fat, %: [seam fat (g)/ pre-dissection cut weight (g)] x 100.

[6] External fat weight (g) includes all fat located on the outer surface of the cut. External fat, %: [external fat (g)/ pre-dissection cut weight (g)] x 100.

[7] Refuse weight (g) includes all bone and heavy connective tissue, include the membrane covering external fat. Refuse, %: [refuse (g)/ pre-dissection (g)] x 100.

Table A.11. All grades raw and cooked least squares means for saturated, unsaturated, and *trans* fatty acid content (g/100 g) of the separable lean from raw and cooked cuts

Retail cut, trim level	Saturated Fatty Acid, g			Monounsaturated Fatty Acid, g			Polyunsaturated Fatty Acid, g			Trans Fatty Acid, g		
	All Grades	SEM	*P*-value	All Grades	SEM	*P*-value	All Grades	SEM	*P*-value	All Grades	SEM	*P*-value
Number of carcasses	36	-		36	-		36	-		36	-	
Raw loin			0.070			0.043			0.140			0.089
Porterhouse steak, 0.32 cm	2.6	0.14		2.6[a]	0.08		0.30	0.018		0.35	0.013	
T-bone steak, 0.32 cm	2.5	0.31		2.5[a]	0.28		0.29	0.037		0.31	0.090	
Tenderloin roast/steak, 0 cm[1]	2.0	0.01		1.9[b]	0.15		0.37	0.024		0.30	0.024	
Top loin steak, 0 and 0.32 cm[2]	2.3	0.30		2.4[a]	0.32		0.33	0.050		0.32	0.035	
Raw round			0.792			0.855			0.707			0.720
Eye of round roast/steak, 0 cm[3]	1.1	0.084		1.1	0.12		0.21	0.019		0.153	0.012	
Top round roast/steak, 0 cm[4]	1.1	0.16		1.2	0.17		0.20	0.028		0.15	0.020	
Cooked[5] *loin*			<0.001			0.007			0.044			0.002
Porterhouse steak, 0.32 cm	4.0[a]	0.14		4.0[ac]	0.11		0.43[bc]	0.041		0.57[a]	0.034	
T-bone steak, 0.32 cm	4.2[a]	0.28		4.1[a]	0.28		0.45[abc]	0.040		0.61[a]	0.049	
Tenderloin roast, 0 cm	3.0[b]	0.15		2.9[bef]	0.28		0.49[ab]	0.021		0.46[b]	0.021	
Tenderloin steak, 0 cm	3.3[b]	0.15		3.3[bdf]	0.49		0.51[a]	0.041		0.48[bc]	0.026	
Top loin steak, 0 cm	3.4[b]	0.35		3.5[cde]	0.41		0.39[c]	0.042		0.48[c]	0.043	
Top loin steak, 0.32 cm	3.3[b]	0.22		3.6[acd]	0.32		0.43[bc]	0.040		0.49[c]	0.034	

[1] Least squares means generated for raw, tenderloin roasts were used to represent values for raw, tenderloin steaks.
[2] Least squares means generated for raw, top loin steaks, 0.32 cm were used to represent values for raw, top loin steaks, 0 cm trim.
[3] Least squares means generated for raw, eye of round roasts were used to represent values for raw, eye of round steaks.
[4] Least squares means generated for raw, top round roasts were used to represent values for raw, top round steaks.
[5] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.
[a-f] Within a column and raw/cook primal, least squares means lacking a common superscript letter differ ($P < 0.05$).

Table A.12. Fatty acid profile of separable lean from raw and cooked[1] porterhouse steaks with 0.32 cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	0.08	0.08	0.12	0.023	0.07	0.08	0.11	0.026
C12:0	Lauric	0.09	0.08	0.10	0.002	0.08	0.08	0.10	0.011
C14:0	Myristic	2.71	2.79	3.19	0.141	2.89	2.93	2.99	0.147
C14:1	Myristicoleic	0.71	0.69	0.73	0.088	0.77	0.75	0.73	0.081
C15:0	Pentadecanoic	0.42	0.46	0.59	0.019	0.44	0.46	0.55	0.022
C16:0	Palmitic	24.98	25.08	25.97	0.814	25.10	25.09	25.41	0.754
C16:1*c*	Palmitoleic	3.04	3.30	3.25	0.171	3.24	3.40	3.04	0.362
C16:1*t*		0.28	0.30	0.28	0.040	0.29	0.30	0.33	0.037
C17:0	Heptadecanoic	1.15	1.23	1.38	0.044	1.15	1.24	1.34	0.046
C17:1	Heptadecenoic	0.81	0.89	0.94	0.142	0.80	0.90	0.92	0.053
C18:0	Stearic	14.57	13.87	14.11	0.379	14.55	13.88	14.66	0.444
C18:1*c*	Oleic	41.21	39.50	37.22	0.924	40.50	39.72	38.40	1.157
C18:1*t*		4.12	4.89	5.39	0.447	4.39	5.01	5.42	0.280
C18:2 CLA		0.38	0.41	0.34	0.063	0.42	0.40	0.36	0.073
C18:2n-6	Linoleic	3.39	4.21	4.02	0.433	3.42	3.81	3.53	0.446
C18:2*t*		0.56	0.51	0.55	0.023	0.55	0.56	0.58	0.048
C18:3n-3	Linolenic	0.21	0.20	0.17	0.027	0.22	0.19	0.16	0.017
C20:0	Arachidic	0.07	0.06	0.07	0.014	0.07	0.06	0.06	0.014
C20:1	Eicosenoic	0.24	0.24	0.20	0.055	0.21	0.23	0.24	0.044
C20:2n-6	Eicosadienoic	0.02	0.03	0.02	0.004	0.03	0.03	0.02	0.009
C20:3n-6	Eicosatrienoic	0.20	0.23	0.29	0.021	0.17	0.18	0.22	0.031
C20:4n-6	Arachidonic	0.54	0.69	0.76	0.029	0.43	0.52	0.60	0.092
C20:5n-3	Eicosapentaenoic	0.03	0.03	0.04	0.017	0.03	0.02	0.03	0.011
C22:5n-3	Docosapentaenoic	0.13	0.14	0.19	0.023	0.12	0.11	0.13	0.018
C22:6n-3	Docosahexaenoic	0.01	0.01	0.02	0.010	0.01	0.01	0.01	0.009
C24:0	Lignoceric	0.05	0.06	0.06	0.042	0.05	0.05	0.05	0.037

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A.13. Fatty acid profile of separable lean from raw and cooked[1] T-bone steaks with 0.32 cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	0.09	0.12	0.16	0.023	0.10	0.12	0.11	0.026
C12:0	Lauric	0.08	0.08	0.10	0.008	0.09	0.11	0.11	0.011
C14:0	Myristic	2.87	2.71	3.06	0.141	2.91	2.91	3.12	0.147
C14:1	Myristicoleic	0.58	0.65	0.61	0.088	0.65	0.61	0.56	0.081
C15:0	Pentadecanoic	0.42	0.39	0.55	0.019	0.45	0.46	0.60	0.022
C16:0	Palmitic	25.62	24.92	25.66	0.814	25.57	25.02	25.84	0.754
C16:1*c*	Palmitoleic	3.23	3.18	3.09	0.171	3.17	3.51	3.13	0.362
C16:1*t*		0.27	0.24	0.33	0.040	0.29	0.29	0.32	0.037
C17:0	Heptadecanoic	1.20	1.25	1.36	0.044	1.17	1.22	1.38	0.046
C17:1	Heptadecenoic	0.65	0.87	0.93	0.142	0.80	0.91	0.94	0.053
C18:0	Stearic	14.57	14.59	14.49	0.379	14.73	14.21	14.81	0.417
C18:1*c*	Oleic	41.00	40.02	38.10	0.924	39.89	39.45	37.00	1.157
C18:1*t*		3.33	4.45	4.93	0.447	4.53	5.09	5.75	0.280
C18:2 CLA		0.40	0.32	0.32	0.063	0.39	0.40	0.36	0.073
C18:2n-6	Linoleic	3.69	3.89	3.86	0.433	3.34	3.76	3.78	0.446
C18:2*t*		0.55	0.49	0.54	0.078	0.58	0.58	0.72	0.048
C18:3n-3	Linolenic	0.21	0.17	0.18	0.027	0.21	0.19	0.17	0.010
C20:0	Arachidic	0.06	0.07	0.06	0.014	0.06	0.06	0.06	0.014
C20:1	Eicosenoic	0.18	0.21	0.19	0.055	0.20	0.21	0.15	0.044
C20:2n-6	Eicosadienoic	0.02	0.04	0.03	0.006	0.02	0.03	0.03	0.002
C20:3n-6	Eicosatrienoic	0.20	0.26	0.32	0.021	0.17	0.19	0.20	0.031
C20:4n-6	Arachidonic	0.55	0.75	0.80	0.092	0.47	0.52	0.62	0.092
C20:5n-3	Eicosapentaenoic	0.02	0.04	0.04	0.017	0.02	0.03	0.03	0.011
C22:5n-3	Docosapentaenoic	0.14	0.18	0.21	0.023	0.13	0.12	0.13	0.018
C22:6n-3	Docosahexaenoic	0.00	0.00	0.00	0.010	0.00	0.00	0.00	0.009
C24:0	Lignoceric	0.06	0.07	0.07	0.042	0.03	0.05	0.03	0.037

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A.14. Fatty acid profile of separable lean from raw and cooked[1] tenderloin roasts with 0cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	0.08	0.11	0.13	0.023	0.11	0.10	0.09	0.026
C12:0	Lauric	0.09	0.08	0.10	0.007	0.11	0.11	0.11	0.011
C14:0	Myristic	2.61	2.87	2.79	0.141	2.68	2.83	2.74	0.147
C14:1	Myristicoleic	0.61	0.67	0.60	0.088	0.66	0.70	0.55	0.081
C15:0	Pentadecanoic	0.45	0.54	0.55	0.019	0.47	0.52	0.51	0.022
C16:0	Palmitic	23.96	24.21	23.69	0.814	24.45	24.26	24.06	0.754
C16:1*c*	Palmitoleic	2.87	2.94	2.64	0.171	3.05	2.97	2.56	0.362
C16:1*t*		0.37	0.43	0.41	0.040	0.37	0.38	0.39	0.037
C17:0	Heptadecanoic	1.21	1.30	1.29	0.044	1.24	1.28	1.32	0.046
C17:1	Heptadecenoic	0.87	0.90	0.85	0.142	0.89	0.92	0.86	0.053
C18:0	Stearic	14.33	14.15	15.23	0.379	14.33	14.22	15.21	0.929
C18:1*c*	Oleic	37.71	37.49	36.50	0.924	38.99	38.46	36.69	1.157
C18:1*t*		4.80	4.98	5.13	0.447	4.48	4.81	5.41	0.280
C18:2 CLA		0.52	0.57	0.57	0.063	0.48	0.52	0.58	0.073
C18:2n-6	Linoleic	6.57	5.53	6.10	0.433	5.26	5.15	5.96	0.446
C18:2*t*		0.55	0.68	0.63	0.039	0.57	0.63	0.58	0.048
C18:3n-3	Linolenic	0.20	0.27	0.28	0.027	0.18	0.23	0.22	0.031
C20:0	Arachidic	0.09	0.09	0.08	0.014	0.08	0.08	0.09	0.014
C20:1	Eicosenoic	0.23	0.23	0.24	0.055	0.21	0.20	0.21	0.044
C20:2n-6	Eicosadienoic	0.04	0.05	0.05	0.021	0.05	0.04	0.04	0.019
C20:3n-6	Eicosatrienoic	0.30	0.38	0.38	0.021	0.23	0.27	0.29	0.031
C20:4n-6	Arachidonic	1.21	1.22	1.32	0.031	0.87	0.99	1.16	0.092
C20:5n-3	Eicosapentaenoic	0.06	0.06	0.07	0.017	0.03	0.04	0.04	0.011
C22:5n-3	Docosapentaenoic	0.15	0.22	0.24	0.023	0.12	0.15	0.19	0.018
C22:6n-3	Docosahexaenoic	0.02	0.00	0.04	0.010	0.00	0.03	0.03	0.009
C24:0	Lignoceric	0.09	0.11	0.10	0.042	0.09	0.10	0.11	0.037

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A.15. Fatty acid profile of separable lean from cooked[1] tenderloin steaks with 0cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	-	-	-	-	0.10	0.12	0.12	0.026
C12:0	Lauric	-	-	-	-	0.08	0.09	0.08	0.011
C14:0	Myristic	-	-	-	-	2.85	2.95	2.92	0.147
C14:1	Myristicoleic	-	-	-	-	1.12	1.18	1.11	0.089
C15:0	Pentadecanoic	-	-	-	-	0.48	0.52	0.56	0.022
C16:0	Palmitic	-	-	-	-	24.64	24.78	24.63	0.754
C16:1*c*	Palmitoleic	-	-	-	-	3.45	3.46	3.12	0.362
C16:1*t*		-	-	-	-	0.37	0.41	0.39	0.037
C17:0	Heptadecanoic	-	-	-	-	1.16	1.22	1.23	0.046
C17:1	Heptadecenoic	-	-	-	-	0.90	0.97	0.90	0.053
C18:0	Stearic	-	-	-	-	13.65	13.67	14.60	1.473
C18:1*c*	Oleic	-	-	-	-	38.80	38.85	37.48	1.157
C18:1*t*		-	-	-	-	4.65	4.71	4.98	0.280
C18:2 CLA		-	-	-	-	0.55	0.51	0.56	0.073
C18:2n-6	Linoleic	-	-	-	-	5.27	4.75	5.09	0.446
C18:2*t*		-	-	-	-	0.63	0.64	0.60	0.048
C18:3n-3	Linolenic	-	-	-	-	0.21	0.25	0.27	0.025
C20:0	Arachidic	-	-	-	-	0.08	0.08	0.08	0.014
C20:1	Eicosenoic	-	-	-	-	0.21	0.19	0.18	0.044
C20:2n-6	Eicosadienoic	-	-	-	-	0.05	0.04	0.04	0.018
C20:3n-6	Eicosatrienoic	-	-	-	-	0.24	0.28	0.31	0.031
C20:4n-6	Arachidonic	-	-	-	-	0.86	0.96	0.98	0.092
C20:5n-3	Eicosapentaenoic	-	-	-	-	0.03	0.05	0.06	0.011
C22:5n-3	Docosapentaenoic	-	-	-	-	0.12	0.18	0.20	0.018
C22:6n-3	Docosahexaenoic	-	-	-	-	0.01	0.01	0.03	0.009
C24:0	Lignoceric	-	-	-	-	0.05	0.04	0.06	0.037

[1] Steak cuts were grilled to an internal temperature of 70^{o}C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60^{o}C.

Table A.16. Fatty acid profile of separable lean from raw and cooked[1] top loin steaks with 0.32 cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	0.11	0.11	0.12	0.023	0.11	0.12	0.11	0.026
C12:0	Lauric	0.09	0.10	0.09	0.010	0.09	0.10	0.10	0.011
C14:0	Myristic	2.82	2.79	2.74	0.141	2.75	2.95	2.78	0.147
C14:1	Myristicoleic	0.62	0.65	0.46	0.088	0.58	0.60	0.53	0.081
C15:0	Pentadecanoic	0.43	0.46	0.52	0.019	0.43	0.50	0.26	0.022
C16:0	Palmitic	25.27	24.84	24.97	0.814	25.03	25.23	24.77	0.754
C16:1*c*	Palmitoleic	3.54	3.46	3.15	0.171	3.41	3.58	3.12	0.362
C16:1*t*		0.24	0.27	0.32	0.040	0.26	0.27	0.29	0.037
C17:0	Heptadecanoic	1.12	1.23	1.24	0.044	1.17	1.26	1.28	0.046
C17:1	Heptadecenoic	0.88	0.96	0.88	0.142	0.89	0.98	0.95	0.053
C18:0	Stearic	13.24	13.07	13.73	0.379	13.57	13.04	14.20	0.416
C18:1*c*	Oleic	40.00	40.53	38.92	0.924	41.07	40.11	38.95	1.157
C18:1*t*		4.17	4.61	5.04	0.447	4.36	5.00	5.21	0.280
C18:2 CLA		0.41	0.45	0.45	0.063	0.39	0.42	0.44	0.073
C18:2n-6	Linoleic	4.77	4.25	4.76	0.433	4.09	3.90	4.61	0.446
C18:2*t*		0.51	0.52	0.69	0.030	0.53	0.56	0.53	0.048
C18:3n-3	Linolenic	0.14	0.17	0.17	0.027	0.12	0.16	0.18	0.013
C20:0	Arachidic	0.08	0.05	0.07	0.014	0.05	0.05	0.06	0.014
C20:1	Eicosenoic	0.18	0.17	0.19	0.055	0.20	0.17	0.22	0.044
C20:2n-6	Eicosadienoic	0.03	0.02	0.03	0.004	0.02	0.03	0.02	0.004
C20:3n-6	Eicosatrienoic	0.24	0.22	0.30	0.021	0.17	0.20	0.24	0.031
C20:4n-6	Arachidonic	0.85	0.87	0.84	0.210	0.55	0.59	0.86	0.092
C20:5n-3	Eicosapentaenoic	0.04	0.05	0.04	0.017	0.02	0.02	0.06	0.011
C22:5n-3	Docosapentaenoic	0.14	0.14	0.18	0.023	0.09	0.12	0.19	0.018
C22:6n-3	Docosahexaenoic	0.00	0.01	0.00	0.010	0.01	0.00	0.00	0.009
C24:0	Lignoceric	0.09	0.09	0.08	0.042	0.05	0.03	0.06	0.037

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A.17. Fatty acid profile of separable lean from cooked[1] top loin steaks with 0 cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Raw				Cooked			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	-	-	-	-	0.12	0.14	0.15	0.026
C12:0	Lauric	-	-	-	-	0.09	0.09	0.09	0.011
C14:0	Myristic	-	-	-	-	3.03	3.04	3.04	0.147
C15:0	Pentadecanoic	-	-	-	-	0.43	0.49	0.51	0.022
C16:0	Palmitic	-	-	-	-	25.90	25.58	25.36	0.754
C16:1*c*	Palmitoleic	-	-	-	-	3.42	3.46	3.21	0.362
C16:1*t*		-	-	-	-	0.33	0.33	0.34	0.037
C17:0	Heptadecanoic	-	-	-	-	1.16	1.24	1.34	0.046
C17:1	Heptadecenoic	-	-	-	-	0.91	0.95	0.94	0.053
C18:0	Stearic	-	-	-	-	12.91	13.02	13.88	0.450
C18:1*c*	Oleic	-	-	-	-	40.71	41.04	38.46	1.157
C18:1*t*		-	-	-	-	4.31	4.50	5.40	0.280
C18:2 CLA		-	-	-	-	0.55	0.56	0.58	0.073
C18:2n-6	Linoleic	-	-	-	-	4.14	3.45	4.22	0.446
C18:2*t*		-	-	-	-	0.52	0.56	0.61	0.048
C18:3n-3	Linolenic	-	-	-	-	0.16	0.17	0.20	0.003
C20:0	Arachidic	-	-	-	-	0.09	0.10	0.11	0.014
C20:1	Eicosenoic	-	-	-	-	0.30	0.30	0.28	0.044
C20:2n-6	Eicosadienoic	-	-	-	-	0.05	0.03	0.04	0.007
C20:3n-6	Eicosatrienoic	-	-	-	-	0.18	0.21	0.25	0.031
C20:4n-6	Arachidonic	-	-	-	-	0.54	0.52	0.74	0.092
C20:5n-3	Eicosapentaenoic	-	-	-	-	0.03	0.05	0.05	0.011
C22:5n-3	Docosapentaenoic	-	-	-	-	0.10	0.15	0.16	0.018
C22:6n-3	Docosahexaenoic	-	-	-	-	0.00	0.0	0.00	0.009
C24:0	Lignoceric	-	-	-	-	0.02	0.03	0.03	0.037

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A.18. Fatty acid profile of separable lean from raw eye of round roasts and top round roasts with 0 cm trim shown as a percentage of total fatty acids (g/100 g of fat)

Fatty acid, %	Common name	Eye of round roast/steak				Top round roast/steak			
		Upper Choice	Low Choice	Select	SEM	Upper Choice	Low Choice	Select	SEM
C10:0	Capric	0.11	0.12	0.15	0.051	0.12	0.13	0.20	0.051
C12:0	Lauric	0.10	0.08	0.09	0.014	0.09	0.08	0.10	0.014
C14:0	Myristic	2.43	2.76	2.80	0.008	2.54	2.52	2.34	0.008
C14:1	Myristicoleic	0.76	0.85	0.79	0.105	0.73	0.61	0.52	0.033
C15:0	Pentadecanoic	0.43	0.42	0.48	0.044	0.38	0.40	0.39	0.011
C16:0	Palmitic	24.03	24.43	24.53	0.825	24.71	24.07	24.29	0.825
C16:1*c*	Palmitoleic	3.35	3.64	3.24	0.155	3.41	3.26	2.75	0.155
C16:1*t*		0.32	0.36	0.35	0.052	0.25	0.27	0.25	0.052
C17:0	Heptadecanoic	1.08	1.13	1.23	0.052	1.12	1.22	1.27	0.052
C17:1	Heptadecenoic	0.89	0.92	0.96	0.061	0.92	0.94	0.82	0.061
C18:0	Stearic	12.44	12.85	13.40	0.697	12.94	13.67	14.43	0.697
C18:1*c*	Oleic	39.32	39.16	37.50	0.762	41.43	39.78	37.16	0.762
C18:1*t*		4.06	4.40	4.98	0.040	3.48	4.55	5.40	0.107
C18:2 CLA		0.51	0.47	0.48	0.073	0.34	0.39	0.25	0.073
C18:2n-6	Linoleic	6.32	4.87	5.05	0.190	4.51	4.89	6.19	0.570
C18:2*t*		0.66	0.53	0.48	0.124	0.52	0.49	0.36	0.124
C18:3n-3	Linolenic	0.23	0.24	0.22	0.038	0.20	0.17	0.14	0.038
C20:0	Arachidic	0.08	0.08	0.09	0.019	0.06	0.06	0.04	0.019
C20:1	Eicosenoic	0.23	0.30	0.31	0.052	0.26	0.22	0.12	0.052
C20:2n-6	Eicosadienoic	0.06	0.06	0.04	0.016	0.04	0.04	0.05	0.016
C20:3n-6	Eicosatrienoic	0.42	0.44	0.54	0.005	0.43	0.53	0.60	0.005
C20:4		1.55	1.26	1.43	0.238	1.07	1.23	1.70	0.238
C20:5n-3	Eicosapentaenoic	0.11	0.14	0.16	0.048	0.07	0.07	0.10	0.016
C22:5n-3	Docosapentaenoic	0.34	0.35	0.48	0.033	0.29	0.35	0.40	0.033
C22:6n-3	Docosahexaenoic	0.05	0.06	0.11	0.013	0.03	0.02	0.07	0.013
C24:0	Lignoceric	0.12	0.10	0.11	0.029	0.06	0.07	0.09	0.029

[1] Steak cuts were grilled to an internal temperature of 70°C using a clam-shell grill; roasts were cooked in a conventional oven to an internal temperature of 60°C.

Table A19. Fatty acid composition of separable lean from raw and cooked[1] porterhouse steaks with 0.32 cm trim at the six composite level[2]

	Raw						Cooked					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0064	0.0050	0.0055	0.0056	0.0055	0.00147	0.0076	0.0072	0.0073	0.0081	0.0077	0.0021
C12:0	0.0068^{a}	0.0050^{b}	0.0056	0.0047^{b}	0.0052	0.00028	0.0084	0.0074	0.0078	0.0080	0.0079	0.00071
C14:0	0.21^{a}	0.17^{b}	0.18^{z}	0.14^{by}	0.17	0.00873	0.32	0.28	0.29	0.23	0.27	0.025
C14:1	0.055^{a}	0.042^{b}	0.046^{z}	0.033^{by}	0.041	0.0028	0.084	0.072	0.076	0.056	0.068	0.0069
C15:0	0.033	0.027	0.029	0.027	0.028	0.0018	0.048	0.044	0.046	0.042	0.044	0.0041
C16:0	1.95^{a}	1.50^{b}	1.65^{z}	1.17^{by}	1.46	0.090	2.73^{a}	2.40^{a}	2.51^{z}	1.94^{by}	2.28	0.091
C16:1c	0.24^{a}	0.20^{b}	0.21^{z}	0.15^{cy}	0.18	0.008	0.35	0.33	0.34	0.23	0.29	0.029
C16:1t	0.022	0.018	0.019	0.012	0.017	0.0027	0.032	0.028	0.030	0.025	0.028	0.0042
C17:0	0.090	0.073	0.079	0.062	0.072	0.0044	0.13	0.12	0.12	0.10	0.116	0.0060
C17:1	0.064^{a}	0.054^{a}	0.057^{z}	0.042^{by}	0.051	0.0025	0.087	0.086	0.087	0.070	0.081	0.0080
C18:0	1.14^{a}	0.83^{b}	0.93^{z}	0.63^{by}	0.81	0.0451	1.58^{a}	1.33^{b}	1.41^{z}	1.12^{cy}	1.29	0.033
C18:1c	3.22^{a}	2.36^{b}	2.65^{z}	1.67^{cy}	2.26	0.0748	4.41^{a}	3.80^{b}	4.00^{z}	2.92^{cy}	3.57	0.0843
C18:1t	0.32^{a}	0.29^{ab}	0.30^{z}	0.24^{by}	0.28	0.015	0.48	0.48	0.48	0.41	0.45	0.0291
C18:2 CLA	0.029	0.024	0.026	0.015	0.022	0.0033	0.04576	0.03883	0.04114	0.02764	0.03574	0.00648
C18n6	0.27	0.25	0.26	0.18	0.23	0.020	0.37	0.37	0.37	0.27	0.33	0.040
C18:2t	0.044^{a}	0.031^{b}	0.035^{z}	0.024^{cy}	0.030	0.00059	0.060	0.054	0.056	0.044	0.051	0.00354
C18:3n3	0.016^{a}	0.012^{b}	0.014^{z}	0.0076^{cy}	0.011	0.0009	0.024^{a}	0.018^{ab}	0.020^{z}	0.012^{by}	0.017	0.00139
C20:0	0.0053	0.0036	0.0042	0.0030	0.0037	0.00097	0.0077	0.0053	0.0061	0.0045	0.0055	0.00165
C20:1	0.019	0.014	0.016	0.0087	0.013	0.0030	0.023	0.022	0.022	0.018	0.021	0.00386
C20:2n6	0.0018	0.0019	0.0018	0.0010	0.0015	0.00024	0.0034	0.0027	0.0029	0.0018	0.0025	0.00102
C20:3n6	0.015	0.014	0.014	0.013	0.014	0.00121	0.018	0.017	0.018	0.017	0.017	0.0014
C20:4	0.043	0.041	0.042	0.034	0.039	0.0024	0.047	0.050	0.049	0.046	0.048	0.0047
C20:5n3	0.0020	0.0019	0.0019	0.0018	0.0019	0.00046	0.0029	0.0021	0.0024	0.0024	0.0024	0.00058
C22:5n3	0.010	0.0087	0.0092	0.0087	0.0090	0.00125	0.013	0.010	0.011	0.0097	0.010	0.00197
C22:6n3	0.0010	0.00051	0.00068	0.00076	0.00071	0.00079	0.0010	0.0010	0.0010	0.00051	0.00081	0.00066
C24:0	0.0043	0.0035	0.0038	0.0027	0.0033	0.00209	0.0052	0.0049	0.0050	0.0040	0.0046	0.00269

[1] Steaks were grilled on clam-shell grills until an internal temperature of 71°C was obtained.

[2] Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.20. Fatty acid composition of separable lean from raw and cooked[1] T-bone steaks with 0.32 cm trim at the six composite level[2]

	Raw						Cooked					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0070	0.0060	0.0066	0.0075	0.0070	0.00056	0.011	0.012	0.012	0.0087	0.010	0.0030
C12:0	0.0064	0.0042	0.0050	0.0048	0.0049	0.00078	0.010	0.011	0.011	0.0086	0.0098	0.00106
C14:0	0.22	0.15	0.17	0.14	0.16	0.024	0.33	0.29	0.30	0.25	0.29	0.030
C14:1	0.044^{a}	0.035^{b}	0.038^{z}	0.029^{c}	0.035	0.0013	0.072	0.061	0.065	0.044	0.057	0.0088
C15:0	0.032	0.022	0.025	0.026	0.026	0.0039	0.051	0.045	0.047	0.047	0.047	0.0053
C16:0	1.96	1.39	1.58	1.21	1.43	0.17	2.87^{a}	2.48^{ab}	2.61	2.048^{b}	2.38	0.156
C16:1c	0.25	0.18	0.20	0.15	0.18	0.029	0.36	0.35	0.35	0.25	0.31	0.035
C16:1t	0.021	0.013	0.016	0.016	0.016	0.0033	0.033	0.029	0.030	0.025	0.028	0.0058
C17:0	0.092	0.069	0.077	0.064	0.072	0.0103	0.13	0.12	0.12	0.11	0.12	0.011
C17:1	0.052	0.048	0.050	0.044	0.047	0.016	0.091	0.090	0.090	0.075	0.084	0.0010
C18:0	1.11	0.81	0.91	0.69	0.82	0.097	1.65^{a}	1.41^{ab}	1.49	1.17^{b}	1.36	0.082
C18:1c	3.1^{a}	2.2^{ab}	2.5	1.8^{b}	2.2	0.239	4.5^{a}	3.9^{ab}	4.1^{z}	2.9^{by}	3.6	0.234
C18:1t	0.28	0.25	0.25	0.23	0.25	0.078	0.51	0.50	0.50	0.45	0.48	0.035
C18:2 CLA	0.031	0.020	0.023	0.015	0.020	0.0044	0.044	0.039	0.041	0.031	0.037	0.0058
C18n6	0.28	0.21	0.24	0.18	0.21	0.031	0.38	0.37	0.37	0.30	0.34	0.032
C18:2t	0.042	0.028	0.033	0.025	0.030	0.0067	0.066	0.057	0.060	0.057	0.059	0.0069
C18:3n3	0.016	0.0097	0.012	0.0084	0.010	0.00218	0.023^{a}	0.018^{ab}	0.020^{z}	0.014^{by}	0.018	0.0013
C20:0	0.0050	0.0041	0.0044	0.0030	0.0038	0.00082	0.0070	0.0058	0.0062	0.0051	0.0058	0.00111
C20:1	0.013	0.012	0.012	0.0087	0.011	0.0018	0.023^{a}	0.020^{ab}	0.021^{z}	0.012^{by}	0.018	0.0023
C20:2n6	0.0018	0.0020	0.0019	0.0015	0.0018	0.00019	0.0020	0.0025	0.0024	0.0023	0.0023	0.00015
C20:3n6	0.015	0.014	0.015	0.015	0.015	0.0014	0.018	0.019	0.019^{z}	0.016^{y}	0.018	0.00072
C20:4	0.042	0.041	0.041	0.038	0.040	0.0064	0.054	0.052	0.053	0.049	0.051	0.0101
C20:5n3	0.0018	0.0024	0.0022	0.0018	0.0020	0.00078	0.0020	0.0027	0.0025	0.0022	0.0024	0.00077
C22:5n3	0.011	0.010	0.010	0.0097	0.010	0.0011	0.014^{a}	0.012^{b}	0.013^{z}	0.011^{by}	0.012	0.00042
C22:6n3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00025	0.0001	0.00001
C24:0	0.0046	0.0034	0.0038	0.0032	0.0036	0.00245	0.0041	0.0047	0.0045	0.0025	0.0037	0.00384

[1] Steaks were grilled on clam-shell grills until an internal temperature of 71^{o}C was obtained.

[2] Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.21. Fatty acid composition of separable lean from raw top loin steaks with 0.32 cm trim at the six composite level[1]

	Raw					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0064	0.0063	0.0064	0.0055	0.0060	0.00071
C12:0	0.0052[ab]	0.0058[a]	0.0056[z]	0.0043[by]	0.0051	0.00022
C14:0	0.17	0.16	0.16	0.13	0.15	0.023
C14:1	0.038	0.038	0.038	0.021	0.031	0.0096
C15:0	0.026	0.027	0.026	0.025	0.026	0.0036
C16:0	1.5	1.4	1.5	1.2	1.4	0.20
C16:1c	0.21	0.20	0.21	0.15	0.18	0.034
C16:1t	0.015	0.016	0.015	0.016	0.016	0.0038
C17:0	0.067	0.071	0.070	0.059	0.066	0.0061
C17:1	0.053	0.056	0.055	0.043	0.050	0.0060
C18:0	0.79	0.75	0.77	0.66	0.72	0.075
C18:1c	2.4	2.3	2.4	1.9	2.2	0.28
C18:1t	0.25	0.27	0.26	0.24	0.25	0.026
C18:2 CLA	0.025	0.021	0.022	0.022	0.022	0.0046
C18n6	0.28	0.24	0.26	0.23	0.25	0.0395
C18:2t	0.031	0.030	0.030	0.034	0.032	0.0056
C18:3n3	0.008	0.010	0.009	0.008	0.009	0.0021
C20:0	0.0047	0.0031	0.0037	0.0033	0.0035	0.00061
C20:1	0.011	0.010	0.011	0.009	0.010	0.0020
C20:2n6	0.0015	0.0013	0.0014	0.0013	0.0013	0.00021
C20:3n6	0.0142	0.0127	0.0132	0.0142	0.0136	0.0012
C20:4	0.049	0.049	0.049	0.041	0.046	0.010
C20:5n3	0.0023	0.0031	0.0028	0.0021	0.0025	0.00069
C22:5n3	0.0081	0.0081	0.0081	0.0086	0.0083	0.0007
C22:6n3	0.0	0.0005	0.0003	0.0	0.0002	0.00029
C24:0	0.0050	0.0048	0.0049	0.0040	0.0045	0.0031

[1]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.22. Fatty acid composition of separable lean from raw and cooked[1] top loin steaks with 0 cm trim at the six composite level[2]

	Raw						Cooked					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0064	0.0063	0.0064	0.0055	0.0060	0.00071	0.011	0.012	0.012	0.009	0.011	0.0019
C12:0	0.0052^{ab}	0.0058^{a}	0.0056^{z}	0.0043^{by}	0.0051	0.00022	0.0086^{a}	0.0076^{ab}	0.0080^{z}	0.0056^{by}	0.0070	0.00051
C14:0	0.17	0.16	0.16	0.13	0.15	0.023	0.28	0.27	0.27	0.18	0.24	0.027
C14:1	0.038	0.038	0.038	0.021	0.031	0.0096	-	-	-	-	-	-
C15:0	0.026	0.027	0.026	0.025	0.026	0.0036	0.040	0.043	0.042	0.031	0.037	0.0033
C16:0	1.5	1.4	1.5	1.2	1.4	0.20	2.4	2.3	2.3	1.5	2.0	0.23
C16:1c	0.21	0.20	0.21	0.15	0.18	0.034	0.31	0.31	0.31	0.19	0.26	0.050
C16:1t	0.015	0.016	0.015	0.016	0.016	0.0038	0.031	0.029	0.030^{z}	0.021^{y}	0.026	0.0022
C17:0	0.067	0.071	0.070	0.059	0.066	0.0061	0.106	0.108	0.107	0.081	0.097	0.0069
C17:1	0.053	0.056	0.055	0.043	0.050	0.0060	0.083	0.084	0.084	0.057	0.073	0.0087
C18:0	0.79	0.75	0.77	0.66	0.72	0.075	1.19	1.14	1.15	0.84	1.03	0.089
C18:1c	2.4	2.3	2.4	1.9	2.2	0.28	3.7	3.6	3.7	2.3	3.1	0.35
C18:1t	0.25	0.27	0.26	0.24	0.25	0.026	0.39	0.39	0.39	0.33	0.37	0.034
C18:2 CLA	0.025	0.021	0.022	0.022	0.022	0.0046	0.050	0.049	0.049	0.035	0.044	0.0061
C18n6	0.28	0.24	0.26	0.23	0.25	0.0395	0.38	0.30	0.33	0.26	0.30	0.0369
C18:2t	0.031	0.030	0.030	0.034	0.032	0.0056	0.047	0.049	0.048^{z}	0.037^{y}	0.044	0.0029
C18:3n3	0.008	0.010	0.009	0.008	0.009	0.0021	0.015	0.015	0.015	0.012	0.014	0.0016
C20:0	0.0047	0.0031	0.0037	0.0033	0.0035	0.00061	0.0081	0.0086	0.0085	0.0066	0.0077	0.00093
C20:1	0.011	0.010	0.011	0.009	0.010	0.0020	0.027^{a}	0.026^{a}	0.027^{z}	0.017^{by}	0.023	0.0016
C20:2n6	0.0015	0.0013	0.0014	0.0013	0.0013	0.00021	0.0046	0.0025	0.0032	0.0025	0.0030	0.00051
C20:3n6	0.0142	0.0127	0.0132	0.0142	0.0136	0.0012	0.0163^{b}	0.0178^{a}	0.0173^{z}	0.0153^{by}	0.0165	0.00029
C20:4	0.049	0.049	0.049	0.041	0.046	0.010	0.049	0.045	0.047	0.045	0.046	0.0025
C20:5n3	0.0023	0.0031	0.0028	0.0021	0.0025	0.00069	0.0025	0.0041	0.0036	0.0031	0.0034	0.00066
C22:5n3	0.0081	0.0081	0.0081	0.0086	0.0083	0.0007	0.0097	0.0127	0.0117	0.0097	0.0109	0.0015
C22:6n3	0.0	0.0005	0.0003	0.0	0.0002	0.00029	0.0	0.0	0.0	0.0	0.0	0.0
C24:0	0.0050	0.0048	0.0049	0.0040	0.0045	0.0031	0.0020	0.0025	0.0024	0.0015	0.0020	0.0021

[1]Steaks were grilled on clam-shell grills until an internal temperature of 71^{o}C was obtained.
[2]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).
[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.
[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.23. Fatty acid composition of separable lean from raw and cooked tenderloin roasts with 0 cm trim at the six composite level[1]

	Raw						Cooked					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0044	0.0052	0.0049	0.0052	0.0050	0.00131	0.0085	0.0070	0.0075	0.0056	0.0068	0.0011
C12:0	0.0047	0.0036	0.0040	0.0040	0.0040	0.00046	0.0086	0.0077	0.0080	0.0064	0.0074	0.00094
C14:0	0.14[a]	0.13[ab]	0.14	0.11[b]	0.12	0.0069	0.21[a]	0.20[a]	0.21[z]	0.16[by]	0.19	0.0055
C14:1	0.033	0.031	0.032	0.023	0.028	0.0023	0.053[a]	0.050[a]	0.051[z]	0.032[by]	0.044	0.0037
C15:0	0.024	0.025	0.025	0.021	0.023	0.00088	0.038	0.037	0.037	0.030	0.034	0.0020
C16:0	1.3[a]	1.1[ab]	1.2[z]	0.92[by]	1.1	0.05	2.0[a]	1.8[ab]	1.2[z]	1.4[by]	1.7	0.078
C16:1c	0.16	0.14	0.14	0.10	0.13	0.012	0.25	0.21	0.22	0.15	0.19	0.026
C16:1t	0.020[a]	0.020[a]	0.020[z]	0.016[by]	0.018	0.00051	0.029	0.028	0.028	0.023	0.026	0.0014
C17:0	0.066	0.061	0.063	0.050	0.057	0.0060	0.099	0.093	0.095	0.077	0.088	0.0052
C17:1	0.048	0.042	0.044	0.033	0.039	0.0059	0.072	0.066	0.068	0.050	0.061	0.0075
C18:0	0.78[a]	0.66[ab]	0.70	0.59[b]	0.66	0.038	1.1	1.0	1.1	0.89	1.0	0.074
C18:1c	2.1[a]	1.8[ab]	1.9	1.4[b]	1.7	0.14	3.1	2.8	2.9	2.1	2.6	0.25
C18:1t	0.26	0.23	0.24	0.20	0.22	0.023	0.36	0.35	0.35	0.32	0.34	0.016
C18:2 CLA	0.028	0.023	0.024	0.022	0.024	0.0031	0.038	0.037	0.037	0.034	0.036	0.0050
C18n6	0.36[a]	0.26[b]	0.29	0.24[b]	0.27	0.018	0.42	0.37	0.39	0.35	0.37	0.016
C18:2t	0.030[a]	0.032[a]	0.031[z]	0.024[by]	0.028	0.00059	0.045[a]	0.045[a]	0.045[z]	0.034[by]	0.041	0.0023
C18:3n3	0.011	0.013	0.012	0.011	0.012	0.0013	0.014	0.017	0.016	0.013	0.015	0.0015
C20:0	0.0046	0.0040	0.0042	0.0032	0.0038	0.00058	0.0065	0.0057	0.0060	0.0051	0.0056	0.0015
C20:1	0.012	0.010	0.011	0.0094	0.01033	0.0037	0.017	0.014	0.015	0.012	0.014	0.0041
C20:2n6	0.0023	0.0023	0.0023	0.0020	0.0022	0.00086	0.0036	0.0028	0.0031	0.0023	0.0027	0.00123
C20:3n6	0.016	0.018	0.017	0.015	0.016	0.00072	0.018	0.019	0.019	0.017	0.018	0.0018
C20:4	0.066[a]	0.057[ab]	0.060[z]	0.051[by]	0.056	0.0020	0.069	0.072	0.071	0.068	0.070	0.0077
C20:5n3	0.0031	0.0028	0.0029	0.0028	0.0029	0.0010	0.0023	0.0031	0.0028	0.0025	0.0027	0.00079
C22:5n3	0.0081	0.010	0.0095	0.0092	0.0094	0.0013	0.0097	0.011	0.010	0.011	0.011	0.00093
C22:6n3	0.0010	2.2E-19	0.00034	0.0015	0.00081	0.00066	0.0	0.0020	0.0014	0.0020	0.0016	0.0001
C24:0	0.0052	0.0049	0.00502	0.0039	0.0046	0.0017	0.007	0.008	0.007	0.007	0.007	0.0032

[1]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.24. Fatty acid composition of separable lean from raw and cooked tenderloin steaks with 0 cm trim at the six composite level[1]

	Raw						Cooked					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0044	0.0052	0.00493	0.0052	0.0050	0.00131	0.0095	0.0091	0.0093	0.0078	0.0087	0.00196
C12:0	0.0047	0.0036	0.0040	0.0040	0.004	0.00046	0.0075	0.0066	0.0069	0.0054	0.0063	0.00108
C14:0	0.14[a]	0.13[ab]	0.14	0.11[b]	0.12	0.0069	0.27	0.23	0.24	0.19	0.22	0.018
C14:1	0.033	0.031	0.032	0.023	0.028	0.0023	0.11[a]	0.083[b]	0.093[z]	0.074[cy]	0.086	0.0001
C15:0	0.024	0.025	0.025	0.021	0.023	0.00088	0.045	0.041	0.042	0.036	0.040	0.0022
C16:0	1.3[a]	1.1[ab]	1.2[z]	0.92[by]	1.1	0.056	2.3[a]	1.9[ab]	2.0	1.6[b]	1.9	0.11
C16:1c	0.16	0.14	0.14	0.10	0.13	0.012	0.33	0.27	0.29	0.21	0.26	0.077
C16:1t	0.020[a]	0.020[a]	0.020[z]	0.016[by]	0.018	0.00051	0.035[a]	0.031[ab]	0.032	0.025[b]	0.030	0.0016
C17:0	0.066	0.061	0.063	0.050	0.057	0.0060	0.11[a]	0.094[b]	0.099[z]	0.080[cy]	0.091	0.0022
C17:1	0.048	0.042	0.044	0.033	0.039	0.0059	0.08	0.075	0.078	0.059	0.070	0.0103
C18:0	0.78[a]	0.66[ab]	0.70	0.59[b]	0.66	0.038	1.3[a]	1.0[b]	1.1[z]	0.95[by]	1.1	0.033
C18:1c	2.0[a]	1.7[ab]	1.8	1.4[b]	1.7	0.14	3.7	3.0	3.2	2.5	2.9	0.36
C18:1t	0.26	0.23	0.24	0.20	0.22	0.023	0.44[a]	0.36[ab]	0.39	0.32[b]	0.36	0.021
C18:2 CLA	0.028	0.023	0.025	0.022	0.024	0.0031	0.051	0.039	0.043	0.036	0.040	0.0057
C18n6	0.36[a]	0.26[b]	0.29	0.24[b]	0.27	0.018	0.49[a]	0.36[ab]	0.41	0.33[b]	0.37	0.034
C18:2t	0.030[a]	0.032[a]	0.031[z]	0.024[by]	0.028	0.00059	0.060	0.049	0.053	0.039	0.047	0.0075
C18:3n3	0.011	0.013	0.012	0.011	0.012	0.0013	0.020	0.019	0.020	0.018	0.019	0.0015
C20:0	0.0046	0.0040	0.0042	0.0032	0.0038	0.00058	0.0074	0.0064	0.0067	0.0054	0.0062	0.00072
C20:1	0.012	0.010	0.011	0.0094	0.010	0.0037	0.019	0.015	0.016	0.012	0.0142	0.0039
C20:2n6	0.0023	0.0023	0.0023	0.0020	0.0022	0.00086	0.0043	0.0031	0.0035	0.0023	0.0030	0.0013
C20:3n6	0.016	0.018	0.017	0.015	0.016	0.00072	0.022	0.022	0.022	0.020	0.021	0.0013
C20:4	0.066[a]	0.057[ab]	0.060[z]	0.051[by]	0.056	0.0020	0.081[a]	0.073[ab]	0.076	0.064[b]	0.071	0.0036
C20:5n3	0.0031	0.0028	0.0029	0.0028	0.0029	0.0010	0.0025	0.0041	0.0036	0.0036	0.0036	0.0015
C22:5n3	0.00814	0.01017	0.0095	0.00916	0.00936	0.00131	0.01119	0.01373	0.01289	0.01272	0.01282	0.0015
C22:6n3	0.0010	2.2E-19	0.00034	0.0015	0.00081	0.00066	0.0010	0.0010	0.0010	0.0020	0.0014	0.00144
C24:0	0.0052	0.0049	0.0050	0.0039	0.0046	0.0017	0.0049	0.0035	0.004	0.0039	0.0040	0.00366

[2]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.25. Fatty acid composition of separable lean from raw eye of round roasts and steaks with 0 cm trim at the six composite level[1]

	Eye of Round Roast						Eye of Round Steak					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0032	0.0033	0.0033	0.0034	0.0033	0.0012	0.0032	0.0033	0.0033	0.0034	0.0033	0.0012
C12:0	0.0029[a]	0.0020[b]	0.0023	0.0020[b]	0.0022	0.00012	0.0029[a]	0.0020[b]	0.0023	0.0020[b]	0.0022	0.00012
C14:0	0.070	0.073	0.072	0.066	0.070	0.0058	0.070	0.073	0.072	0.066	0.070	0.0058
C14:1	0.022	0.023	0.023	0.018	0.021	0.0034	0.022	0.023	0.023	0.018	0.021	0.0034
C15:0	0.012	0.011	0.012	0.011	0.011	0.00083	0.012	0.011	0.012	0.011	0.011	0.00083
C16:0	0.69	0.65	0.67	0.58	0.63	0.055	0.69	0.65	0.67	0.58	0.63	0.055
C16:1c	0.097	0.097	0.097	0.076	0.089	0.011	0.097	0.097	0.097	0.076	0.089	0.011
C16:1t	0.0092	0.0097	0.0095	0.0081	0.0090	0.0016	0.0092	0.0097	0.0095	0.0081	0.0090	0.0016
C17:0	0.031	0.030	0.030	0.029	0.030	0.0023	0.031	0.030	0.030	0.029	0.030	0.0023
C17:1	0.026	0.024	0.025	0.023	0.024	0.0020	0.026	0.024	0.025	0.023	0.024	0.0020
C18:0	0.36	0.34	0.35	0.32	0.33	0.031	0.36	0.34	0.35	0.32	0.33	0.031
C18:1c	1.1	1.0	1.1	0.89	1.0	0.100	1.1	1.0	1.1	0.89	1.0	0.100
C18:1t	0.12	0.12	0.12	0.12	0.12	0.0085	0.12	0.12	0.12	0.12	0.12	0.0085
C18:2 CLA	0.015	0.013	0.013	0.011	0.012	0.0022	0.015	0.013	0.013	0.011	0.012	0.0022
C18n6	0.18	0.13	0.15	0.12	0.14	0.011	0.18	0.13	0.15	0.12	0.14	0.011
C18:2t	0.019	0.014	0.016	0.011	0.014	0.0024	0.019	0.014	0.016	0.011	0.014	0.0024
C18:3n3	0.0066	0.0066	0.0066	0.0051	0.0060	0.0015	0.0066	0.0066	0.0066	0.0051	0.0060	0.0015
C20:0	0.0023	0.0021	0.0022	0.0022	0.0022	0.00045	0.0023	0.0021	0.0022	0.0022	0.0022	0.00045
C20:1	0.0060	0.0080	0.0070	0.0070	0.0070	0.0017	0.0060	0.0080	0.0070	0.0070	0.0070	0.0017
C20:2n6	0.0015	0.0015	0.0015	0.0010	0.0013	0.00042	0.0015	0.0015	0.0015	0.0010	0.0013	0.00042
C20:3n6	0.012	0.012	0.012	0.013	0.012	0.00072	0.012	0.012	0.012	0.013	0.012	0.00072
C20:4	0.045	0.034	0.038	0.033	0.036	0.0062	0.045	0.034	0.038	0.033	0.036	0.0062
C20:5n3	0.0031	0.0038	0.0036	0.0038	0.0037	0.0012	0.0031	0.0038	0.0036	0.0038	0.0037	0.0012
C22:5n3	0.0097	0.0092	0.0093	0.0112	0.0101	0.0012	0.0097	0.0092	0.0093	0.011	0.010	0.0012
C22:6n3	0.0015	0.0015	0.0015	0.0025	0.0019	0.00051	0.0015	0.0015	0.0015	0.0025	0.0019	0.00051
C24:0	0.0037	0.0026	0.0030	0.0026	0.0028	0.0011	0.0037	0.0026	0.0030	0.0026	0.0028	0.0011

[1]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).
[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

Table A.26. Fatty acid composition of separable lean from raw top round roasts and steaks with 0 cm trim at the six composite level[1]

	Top Round Roast						Top Round Steak					
Fatty acid, g/100 g	Upper Choice	Low Choice	Choice	Select	All Grades	SEM	Upper Choice	Low Choice	Choice	Select	All Grades	SEM
C10:0	0.0042	0.0037	0.0039	0.0043	0.0040	0.0014	0.0042	0.0037	0.0039	0.0043	0.0040	0.0014
C12:0	0.0032	0.0023	0.0026	0.0022	0.0024	0.00082	0.0032	0.0023	0.0026	0.0022	0.0024	0.00082
C14:0	0.088	0.068	0.075	0.050	0.065	0.0086	0.088	0.068	0.075	0.050	0.065	0.0086
C14:1	0.025[a]	0.017[ab]	0.019	0.011[b]	0.016	0.0026	0.025[a]	0.017[ab]	0.019	0.011[b]	0.016	0.0026
C15:0	0.013	0.011	0.012	0.008	0.010	0.0017	0.013	0.011	0.012	0.008	0.010	0.0017
C16:0	0.86	0.66	0.73	0.52	0.64	0.11	0.86	0.66	0.73	0.52	0.64	0.11
C16:1c	0.12	0.089	0.099	0.059	0.083	0.014	0.12	0.089	0.099	0.059	0.083	0.014
C16:1t	0.0086	0.0072	0.0076	0.0053	0.0067	0.0012	0.0086	0.0072	0.0076	0.0053	0.0067	0.0012
C17:0	0.039	0.033	0.035	0.027	0.032	0.0038	0.039	0.033	0.035	0.027	0.032	0.0038
C17:1	0.032	0.025	0.027	0.018	0.023	0.0028	0.032	0.025	0.027	0.018	0.023	0.0028
C18:0	0.45	0.37	0.40	0.31	0.36	0.042	0.45	0.37	0.40	0.31	0.36	0.042
C18:1c	1.4	1.1	1.2	0.79	1.0	0.15	1.4	1.1	1.2	0.79	1.0	0.15
C18:1t	0.121	0.123	0.122	0.115	0.119	0.016	0.121	0.123	0.122	0.115	0.119	0.016
C18:2 CLA	0.0117	0.0102	0.0107	0.0053	0.0086	0.0015	0.0117	0.0102	0.0107	0.0053	0.0086	0.0015
C18n6	0.16	0.13	0.14	0.13	0.14	0.019	0.16	0.13	0.14	0.13	0.14	0.019
C18:2t	0.018	0.013	0.015	0.008	0.012	0.0032	0.018	0.013	0.015	0.008	0.012	0.0032
C18:3n3	0.0068[a]	0.0044[ab]	0.0052	0.0031[b]	0.0044	0.00064	0.0068[a]	0.0044[ab]	0.0052	0.0031[b]	0.0044	0.00064
C20:0	0.0022	0.0016	0.0018	0.0008	0.0014	0.00043	0.0022	0.0016	0.0018	0.0008	0.0014	0.00043
C20:1	0.0091[a]	0.0057[ab]	0.0069[z]	0.0025[by]	0.0051	0.00084	0.0091[a]	0.0057[ab]	0.0069[z]	0.0025[by]	0.0051	0.00084
C20:2n6	0.0015	0.0010	0.0012	0.0010	0.0011	0.00001	0.0015	0.0010	0.0012	0.0010	0.0011	0.00001
C20:3n6	0.015	0.014	0.014	0.013	0.014	0.00051	0.015	0.014	0.014	0.013	0.014	0.00051
C20:4	0.037	0.033	0.035	0.036	0.035	0.0079	0.037	0.033	0.035	0.036	0.035	0.0079
C20:5n3	0.0024	0.0020	0.0021	0.0020	0.0021	0.00058	0.0024	0.0020	0.0021	0.0020	0.0021	0.00058
C22:5n3	0.0102	0.0092	0.0095	0.0086	0.0092	0.00066	0.010	0.0092	0.0095	0.0086	0.0092	0.00066
C22:6n3	0.0010	0.0005	0.0007	0.0015	0.0010	0.00042	0.0010	0.0005	0.0007	0.0015	0.0010	0.00042
C24:0	0.0022	0.0018	0.0019	0.0019	0.0019	0.00071	0.0037	0.0026	0.0030	0.0026	0.0028	0.0011

[1]Six-level composite samples contain separable lean from six animals of the same quality grade (Low Choice, Upper Choice, or Select).

[a-c] Within a row (Upper Choice, Low Choice, and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

[y,z] Within a row (Choice and Select) and Raw/Cooked, means without a common superscript differ ($P < 0.05$). Means without these superscripts are not significantly different.

APPENDIX B

Table B.1. Percentages of carcasses produced by heifers, steers, and black-hided cattle in the experimental sample (N = 450)

	Heifers, %	Steers, %	A stamp,[1] %
Marbling Category	P = 0.1054	P = 0.1054	P = 0.0011
Slight	49.3	50.7	69.3
Small	57.3	42.7	82.7
Modest+[2]	61.3	38.7	86.0
Maturity	--	--	P = 0.9059
A[3]	56	44	79.6
B-C[4]	56	44	79.1

[1]Carcasses identified with an A stamp were produced by cattle that were predominantly (>51%) black in color.
[2]Modest+ = carcasses with Modest^{00} or greater marbling scores.
[3]A = carcasses exhibiting A^{00} to A^{99} overall maturity.
[4]B-C = carcasses exhibiting B^{00} to C^{99} overall maturity.

Table B.2. Least squares means comparing characteristics of steer and heifer carcasses selected to represent the three marbling categories and two maturity groups

Effect	*N*	Marbling score[1]	Fat thickness, cm	LM area, cm^2	HCW, kg	Yield grade
Sex		*P* = 0.1884	*P* = 0.0048	*P* = 0.0124	*P* = 0.0086	*P* = 0.2235
Steer	198	454	1.32	99.6	409	2.9
Heifer	252	461	1.47	93.2	377	3.0
Marbling category		*P* < 0.0001	*P* < 0.0001	*P* < 0.0001	*P* = 0.6059	*P* < 0.0001
Slight	150	362^{c}	1.13^{c}	100.5^{a}	390	2.4^{c}
Small	150	441^{b}	1.43^{b}	94.9^{b}	393	3.0^{b}
Modest+[2]	150	569^{a}	1.63^{a}	93.7^{b}	395	3.3^{a}
Maturity group		*P* = 0.6271	*P* = 0.7536	*P* = 0.8906	*P* = 0.8645	*P* = 0.8398
A[3]	225	456	1.40	96.4	392	2.9
B-C[4]	225	458	1.39	96.3	393	2.9
Residual SD[5]		41.7	0.50	10.48	37.4	0.78

[1] Slight = 300 to 399, Small = 400 to 499, Modest = 500 to 599.
[2] Modest+ = carcasses with $modest^{00}$ or greater marbling scores.
[3] A = carcasses exhibiting A^{00} to A^{99} overall maturity.
[4] B-C = carcasses exhibiting B^{00} to C^{99} overall maturity.
[5] Standard errors of least squares means may be calculated as $1/\sqrt{n}$ x residual SD for a trait where *n* = number of carcasses in that particular marbling category or maturity level.
[a-c] For the marbling category main effect, means in the same column that do not share a common superscript letter differ (P < 0.05).

Table B.3. Correlations[1] among camera marbling score, overall maturity, panel ratings for beef sensory attributes, and LM shear force measurements

	1	2	3	4	5	6	7	8	9	10	11	12
1. Marbling Score		0.02	0.48	0.47	0.46	0.62	-0.27	-0.15	-0.07	-0.10	-0.50	-0.29
2. Overall Maturity	0.02		-0.05	-0.04	-0.02	-0.03	-0.05	0.07	0.11	0.13	-0.01	0.05
3. Juiciness	0.48	-0.05		0.58	0.46	0.66	0.02	-0.12	-0.11	-0.12	-0.34	-0.23
4. Tenderness	0.47	-0.04	0.58		0.40	0.54	-0.09	-0.10	-0.16	-0.17	-0.61	-0.59
5. Meaty/brothy flavor	0.46	-0.02	0.46	0.40		0.55	-0.27	-0.21	-0.25	-0.09	-0.30	-0.27
6. Buttery/beef fat flavor	0.62	-0.03	0.66	0.54	0.55		-0.17	-0.25	-0.16	-0.18	-0.41	-0.30
7. Bloody/serumy flavor	-0.27	-0.05	0.02	-0.09	-0.27	-0.17		0.09	0.13	-0.11	0.12	0.05
8. Livery/organy flavor	-0.15	0.07	-0.12	-0.10	-0.21	-0.25	0.09		0.15	0.32	0.03	0.03
9. Grassy flavor	-0.07	0.11	-0.11	-0.16	-0.25	-0.16	0.13	0.15		0.20	0.07	0.09
10. Gamey flavor	-0.10	0.13	-0.12	-0.17	-0.09	-0.18	-0.11	0.32	0.20		0.05	0.06
11. WBSF[2]	-0.50	-0.01	-0.34	-0.61	-0.30	-0.41	0.12	0.03	0.07	0.05		0.63
12. SSF[3]	-0.29	0.05	-0.23	-0.59	-0.27	-0.30	0.05	0.03	0.09	0.06	0.63	

[1] Coefficients > 0.10 differ from 1 ($P < 0.01$).
[2] Warner-Bratzler shear force.
[3] Slice shear force.

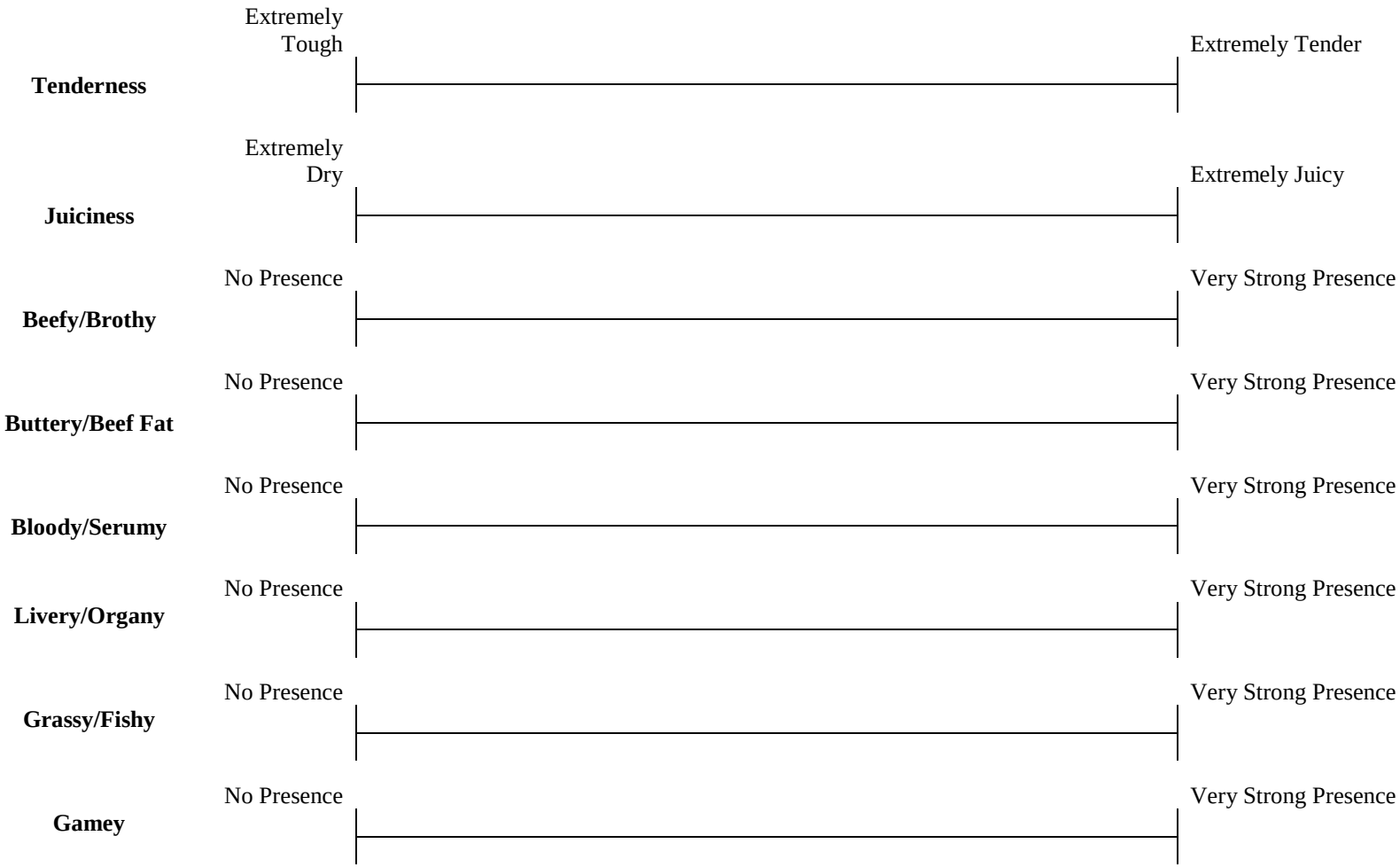

Figure B.1. Sample sensory panel ballot